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These papers are contributions No. 125-133 from the botany laboratories of Butler University.

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THE ORIGIN OF THE FLORA OF THE CHESTNUT OAK UPLAND REGION OF INDIANA[1]

By JOANNA S. GUSS

Indiana may be divided into six distinct botanical regions, each one being different from the others in conditions of soil, moisture, topography, and, consequently, in climate and vegetation. These regions are the Illinois Drift Plain, Prairies, Lake Region including the Dunes, Chestnut Oak Upland, Tipton Till Plain and the Lower Wabash Valley.

The object of this paper is to determine the chief directions of affinities of the species now occurring in the Chestnut Oak Upland region. It deals with the distribution of species comprising the flora both within the state and by physiographic areas outside of the state.

HABITAT FACTORS OF THE CHESTNUT OAK UPLAND

This region is in south central Indiana and includes all or part of the following counties: Bartholomew, Brown, Clark, Crawford, DuBois, Floyd, Greene, Harrison, Jackson, Lawrence, Martin, Monroe, Morgan, Orange, Perry, Scott and Washington. It comprises nearly all of the unglaciated part of the state and a narrow fringe of glaciated territory on the east and north margins. Its relation to other botanical areas of the state is shown in map 1. The surface is an irregular succession of high hills and deep ravines, whose final outlet is into the Ohio river on the south and into the Wabash river on the west. The highest of these hills are over 1200 feet above sea level and have a local relief up to 500 feet.

The soils are mostly residual except in the stream valleys. These residual soil are of limestone, sandstone or knobstone origin. Local habitats have a wide range of variation, varying from sheer limestone, sandstone, and knobstone cliffs, through thin soil layers on the tops of these, high knobs, steep slopes, deep ravines, darkened canyons, outwash plains, and alluvial deposits in stream valleys. There is thus a wide range of micro-climates each with its characteristic flora. According to Visher (5) the average annual rainfall varies from 47 inches in the extreme southern portion to 40 inches in the extreme northern portion of the area. Rainfall for the summer months (June, July and August) averages 10 inches for most of the region but this average reaches 13 inches for a small portion

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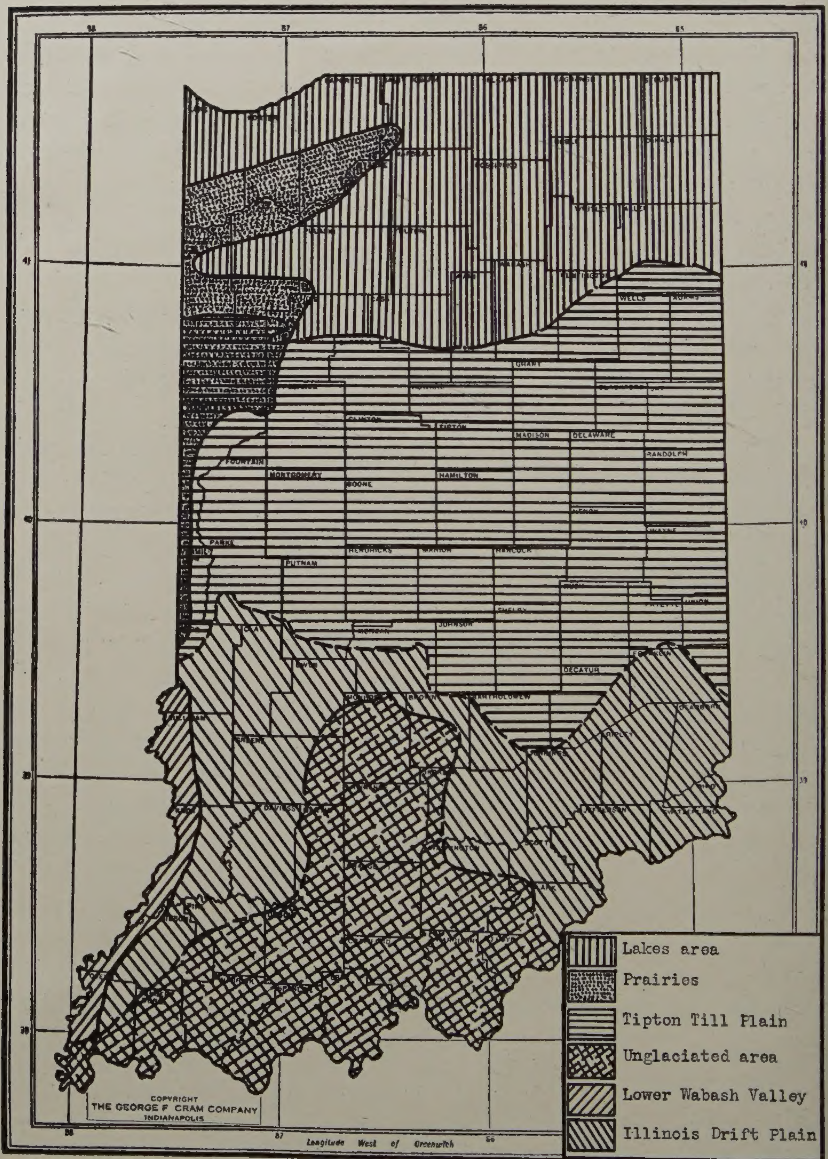
[1] A portion of a thesis submitted to the Faculty of the Division of Graduate Instruction in partial fulfillment of the requirements for the degree Master of Science, in the Department of Botany, Butler University.



of the area near the southwest border. Along with these data the relatively high amount of relief must be taken into consideration inasmuch as this results in a high percentage of run-off and thus makes the area more dependent upon regularity of precipitation than would otherwise be true. The area is subject to erosion to a greater degree than any other part of the state, between 75% and 90% of total area being thus involved. (Visher, 6.)

NATURE OF THE FLORA AND ITS INDIANA DISTRIBUTION

The area under study has a rich and varied flora, 1471 species having come under study in the preparation of this paper. Distribution of these species is based upon the "State Flora Catalog" maintained in the botanical laboratory at Butler University. This catalog is based upon the records in Deam's "Flora" (1) and those published subsequently by the State Flora Committee of the Taxonomic Section of the Indiana Academy of Science (3, 4).

As is to be expected, the larger proportion (75.53%) of the species occurring in the area are to be found in nearly all other botanical areas of the state and the second largest group (12.71%) have their distribution outside the Chestnut Oak Upland, limited chiefly to the southern part of the state. Species exclusive in Indiana to this area comprise 4.89% of the total while a number (6.87% of the total flora) have their Indiana distribution outside of the Chestnut Oak Upland, chiefly northern. These groups will be given more detailed consideration in the following paragraphs and the data here mentioned are summarized in table I.

TABLE I

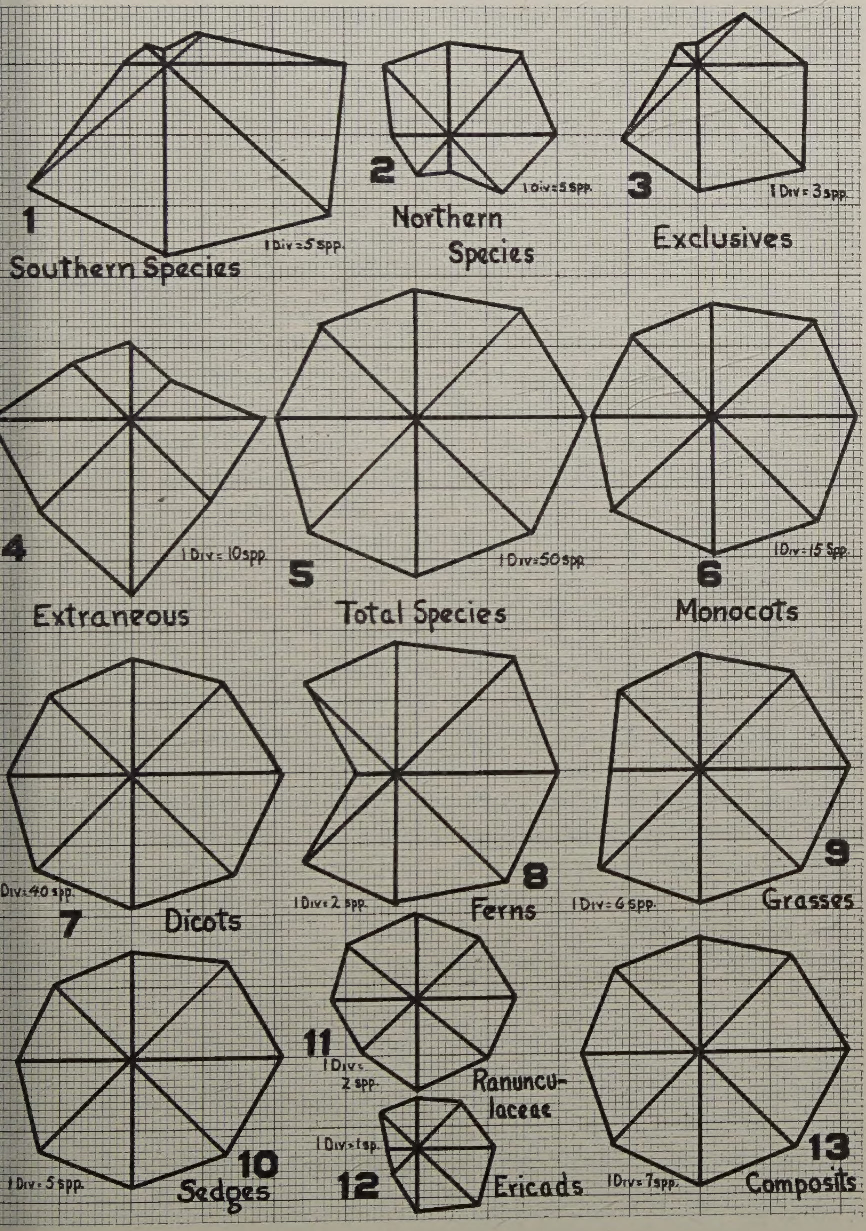
Distributional summary of the species and varieties occurring in the Chestnut Oak Upland.

Species and varieties	Number	Percent
Occurring in this area and in nearly all other botanical areas of the state	1111	75.53
Occurring in this area and with Indiana distribution outside it chiefly southern	187	12.71
Occurring in this area and with Indiana distribution outside it chiefly northern	101	6.87
Exclusive in Indiana to this area	72	4.89
Total Species	1471	100.
Extraneous, i. e. limits of range passes through this area	378	25.69
Coastal plains species	19	1.29

SPECIES OCCURRING IN THE CHESTNUT OAK UPLAND AND WITH DISTRIBUTION OUTSIDE THIS AREA CHIEFLY SOUTHERN

This study has revealed 187 species whose Indiana distribution is chiefly southern though not entirely limited to this area. These plants are almost entirely species whose main distribution outside of this area is eastern and southeastern or eastern through southeastern and southern to southwestern. Figure 1 represents the number of species of this group with main distribution on each of 8 axes of the compass. It will be observed that the largest number of species fall within the southeast quadrant of the compass. The following are some typical examples: *Acalypha ostryaefolia* (recently reported also for Tipton county), *Aesculus octandra, Agave virginica, Agrostis elliottiana, Andropogon elliottiana, Arabis virginica, Aruncus dioicus, Asclepias perennis, A. variegata, Asplenium pinnatifidum, Carya illinoiensis, Cheilanthes lanosa, Cocculus carolinus, Commelina virginica, Corallorrhiza wisteriana, Cornus stricta, Dentaria heterophylla, Desmodium viridiflorum, Elephantopus carolinianus, Habenaria peramoena, Iris cristata, Obolaria virginica, Oxalis grandis, Panicum anceps, P. polyanthes, P. stipitatum, P. xalapense, Poa chapmaniana, Polymnia uvedalia, Rubus argutus, Scutellaria australis, Smilax glauca, Solidago bicolor, S. sphacelata, Ulmus alata, Viburnum pubescens* var. *deamii, V. rufidulum.* Species falling in this group in regard to Indiana distribution but more particularly eastern in general distribution are represented by the following: *Aristida dichotoma, Carex willdenovii, Carya glabra, Castanea dentata, Tsuga canadensis,* and *Vaccinium stamineum.*

Waldsteinia fragarioides is another species of this group whose distribution is significant. While in its general distribution it occurs from northwest through north, east, south to southwest of Indiana, it is found in but three stations within the state, all of which are talus slopes, viz. near the site of Carne's Mill, 2 miles south of Grantsburg in Crawford County, along Buck Creek, north of Dogwood in Harrison County, both of which sites lie within the Chestnut Oak Upland, and along the North Fork of the Muscatatuck River about one-half mile upstream from Vernon in Jennings County (Deam, 1). The fact that a species, intraneous to an area, is so limited in its distribution would appear to bespeak a dearth of local habitats though, from mere casual observation, apparently similar sites can be found in many places within the state yet without this


1
Southern Species
1 Div = 5 spp.
2
Northern Species
1 Div = 5 spp.
3
Exclusives
1 Div = 3 spp.
4
Extraneous
1 Div = 10 spp.
5
Total Species
1 Div = 50 spp.
6
Monocots
1 Div = 15 Spp.
7
Dicots
Div = 40 spp.
8
Ferns
1 Div = 2 spp.
9
Grasses
1 Div = 6 spp.
10
Sedges
1 Div = 5 spp.
11
Ranunculaceae
1 Div = 2 spp.
12
Ericads
1 Div = 1 sp.
13
Composits
1 Div = 7 spp.

species. More detailed habitat studies will be necessary to throw light upon this striking limitation of distribution.

A few species occurring only in and near this area have a general distribution on all sides of Indiana, e. g. *Solidago bicolor, Aster patens, A. undulatus, Dennstaedtia punctilobula* (in Parke County outside this area), *Eragrostis capillaris, Scirpus polyphyllus, Uvularia sessilifolia, Lilium superbum, Polygonatum biflorum.* However, it is apparent that most of the species in this group are on the northern, western or northwestern limits of their range here.

SPECIES OCCURRING IN THE CHESTNUT OAK UPLAND AND WITH DISTRIBUTION OUTSIDE THIS AREA CHIEFLY NORTHERN

One-hundred-one species have been found to occur in the Chestnut Oak Upland with Indiana distribution outside this area limited chiefly to the northern part of the state. This forms an interesting group of species because many of them are northern species reaching the southern limits of their range here. Some of them are northern relicts, e. g. *Betula lutea* var. *macrolepis, Epigaea repens, Gaultheria procumbens, Habenaria ciliaris, H. clavellata, Lycopodium flabelliforme, Trillium grandiflorum,* and *Tsuga canadensis,* and are restricted to one or only a few sites. Among the other species of this group is a considerable number which are absent from the central part of the state: *Acerates viridiflora* found in Harrison County and not again until the sandy areas of the northwestern and northernmost counties are reached; *Aster linariifolius,* rare on the crests of residual clay ridges in Floyd, Harrison and Perry Counties, then skipping to the sandy areas from Cass County westward and northwestward, the latter area being of Late Wisconsin origin; *Brasenia schreberi,* occurring in Jefferson and Monroe Counties, then skipping to the Lakes area; *Bartonia virginica,* occurring in a small bog 10 miles southeast of Bloomington, in three other sites just beyond the edges of the Chestnut Oak Uplands, and then skipping to the Lakes area; *Carex comosa,* found only in Floyd County, in a few sites in the Early Wisconsin drift and then in every county in the Late Wisconsin drift; *C. buxbaumii,* found only in Harrison County, in two counties of the Early Wisconsin drift and then in most of the Late Wisconsin drift area; *C. decomposita,* found only in Lawrence and Wells Counties; *C. intumescens,* found generally in the southern half of the state, skipping over the central part and occurring again in Wells County and the northern two tiers of counties; *Viola pedata,* occurring on heavy clay soils in a number of Chestnut Oak Upland sites, then skipping to the sandy areas of the north and northwest portions of the state; *Liatris scariosa,* occurring on heavy clay soils on ridge tops here, then skipping to the sandy soils of the northern quarter of the state; *Lathyrus venosus,* occurring only in Harrison County, then skipping to Lake and Porter Counties in the extreme northwest corner of the state; *Vaccinium vacillans* var. *crinitum,* found in a number of sites scattered on dry oak ridges and canyon walls here and then skipping to sandy areas of Pulaski and St. Joseph Counties. This disjunct distribution is clearly due to lack of suitable intervening habitats in some cases, e. g. in the case of *Brasenia schreberi,* but in other this is hardly true and, besides, the northern stations are on sandy soils instead of heavy clay. More detailed study of the local edaphic conditions will be necessary to throw more light on the possible factors involved in this peculiar distribution. Other species of the group include: *Bromus kalmii, Cardamine parviflora* var. *arenicola, Carex pennsylvanica, C. scoparia, C. umbellata, Gaylussacia baccata, Gentiana flavida, Lechea villosa, Liatris scariosa, Lysimachia quadrifolia, Desmodium ciliare, D. rigidum, Goodyera pubescens, Hedeoma hispida, Hypericum gentianoides, Kuhnia eupatorioides, Linum sulcatum, Melanthium virginicum, Melica nitens, Oenothera tetragona* var. *longistipata, Panicum praecocius, P. sphaerocarpon, P. flexile, Rumex brittaanica, Rubus abactus, Scrophularia lanceolata, Scutellaria nervosa, S. ovalifolia, Stenanthium robustum* and *Vicia caroliniana.*

Figure 2 shows a graphic representation of the wider distribution of these species. While it is apparent that more of them are eastern to northwestern there is a considerable number that have a wider distribution on all sides of this area. The absence of these species in the central part of Indiana is probably related to edaphic rather than climatic conditions.

EXTRANEOUS AND EXCLUSIVES

Perhaps the most significant feature regarding the wider distribution of species and varieties of this area is the fact that 378 species (25.69% of the total flora) are on the limits of their range as it passes through this area. These are listed, together with the directions of their distribution from the area, in table II. The number showing distribution in each of the 8 directions of the compass is shown graphically in figure 4. The area is terminal for the distribution of species and varieties from all directions but for a larger number from the east, southeast, south, southwest and west than from other directions.

Of the total extraneous forms 72 or 19.1% (4.89% of the total flora) are exclusive in Indiana to this area. Most of these exclusives have their general distribution in the Appalachian highlands to the east, southeast and south. Some extend to the southwest and a smaller number to the northeast with a very few to the north, northwest and west. These species are indicated by an asterisk (*) in table II and the relative numbers are shown graphically in fig. 3.

A small number (14 or 3.7%) of the extraneous forms are Atlantic and Gulf coastal plains forms which have extended up the Mississippi Valley to this area and reach their range limits here. These are indicated by two asterisks (**) in table II.

Friesner (2) has pointed out the critical character of Indiana as a botanical area. In his study 131 species were found to be on the limits of their range within the Chestnut Oak Uplands. The present study lists 378 species. The difference between these figures is due to increased knowledge of Indiana plant distribution due to the publication of Deam's (1) "Flora" subsequent to the former paper.

SYSTEMATIC GROUPS

Figure 5 shows relative numbers of species and varieties of the total flora of the area extending into each of the directions of the compass. It will be noted that the figure so formed presents a greater area eastward of a north-south line than to the west of such a line. Figures 6-13 show other groups, only two of which show a markedly unsymmetrical shape, viz. pteridophytes (fig. 8) and ericads (fig. 12). The dearth of pteridophytes to the west (fig. 8) is undoubtedly due to climatic reasons while the smaller numbers of ericads west of the north-south axis is due to both climatic and habitat reasons.

SUMMARY

1. A total of 1471 species and varieties are known to occur in the Chestnut Oak Uplands of Indiana.

2. The larger percentage (75.53%) of the flora has a distribution generally over the state.

3. The second largest group (25.69% of the total) have their range limits pass through this area.

4. The third largest group (12.71%) is generally southern in its distribution within the state and in its wide distribution occurs very largely southeast of a line drawn through the area from the southwest to the northeast.

5. The fourth largest group (6.87%) has its Indiana distribution outside of this area chiefly in the northern part of the state. A larger percentage of the species of this group extend to the east, northeast, north and northwest than in other directions.

6. The smallest group (4.89%) are exclusive in Indiana to this area. The wider distribution of these forms is chiefly southeast of a line drawn from the area to the southwest and the northeast.

ACKNOWLEDGMENT

The writer wishes to express her sincere thanks to Dr. Ray C. Friesner, who suggested and supervised the preparation of this paper.

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TABLE II

Extraneous species and varieties. Wider distribution of species and varieties which are on the limits of their range in the Chestnut Oak Uplands. *=Exclusive in Indiana to this area. **=Coastal plains species.

	NW	N	NE	E	SE	S	SW	W
*Ophioglossum engelmanni				x	x	x	x	
*Cheilanthes lano			x	x	x	x	x	
Pteretis nodulosa	x	x	x	x				
*Botrychium dissectum var tenuifolium						x		
Asplenium pinnatifidum				x	x		x	
Asplenosorus ebenoides			x				x	
Polypodium polypodioides var. michauxiana				x	x	x	x	
*Lycopodium selago var. patens	x	x	x	x	x			
L. flabelliforme	x	x	x	x	x			

TABLE II—(Continued)

	NW	N	NE	E	SE	S	SW	W
L. lucidulum	x	x	x	x	x			
*Pinus virginiana				x	x			
Tsuga canadensis	x	x	x	x	x			
*Naias gracillima	x	x	x				x	
*Lophotocarpus calycinus	x			x	x	x	x	x
Arundinaria gigantea					x	x	x	
*Poa cuspidata				x	x			
Bromus kalmii	x	x	x	x				
*Glyceria acutiflora			x	x	x			
Uniola latifolia				x	x	x	x	
*Melica mutica				x	x	x	x	x
Aristida dichotoma			x	x	x	x	x	
A. ramosissima						x	x	x
Leptochloa filiformis					x	x	x	
*Muhlenbergia capillaris			x	x	x	x	x	x
Paspalum fluitans					x	x	x	
Panicum anceps				x	x	x	x	
P. stipitatum			x	x	x	x	x	
P. xalapense				x	x	x	x	x
*P. bicknellii			x	x	x	x	x	
P. microcarpon			x	x	x	x	x	
*P. mattamuskeetense**			x	x	x			
*P. yadkinense				x	x	x	x	x
P. polyanthes			x	x	x	x	x	
P. leibergii	x	x	x					x
*Erianthus alopecuroides				x	x	x	x	
Andropogon elliottii				x	x	x	x	
Cyperus elliottii				x	x	x	x	
C. ovularis			x	x	x	x	x	
C. filiculmis var. macilentus	x	x	x	x				x
Kyllingia pumila				x	x	x	x	
Scirpus eriophorum**			x	x	x	x		
S. pedicellatus	x		x					
Eleocharis smallii			x	x			x	x
E. elliptica	x	x	x	x	x			x
E. tenuis					x	x	x	
Rhynchospora corniculata var. interior						x	x	
*Scleria oligantha					x	x	x	
Carex retroflexa			x	x	x	x	x	
C. mesochorea			x	x	x			
C. decomposita			x	x	x	x	x	
C. crus-corvi	x				x	x	x	x
C. conjuncta	x			x				x
C. tenera	x	x	x	x	x			x
C. molesta			x					x
C. richii			x	x				

TABLE II—(Continued)

	NW	N	NE	E	SE	S	SW	W
C. albolutescens**			x	x	x	x	x	
C. willdenowii			x	x	x	x	x	
*C. nigromarginata**			x	x	x	x	x	
C. umbellata	x	x	x	x				x
*C. picta						x		
C. careyana	x	x	x	x				x
C. platyphylla	x	x	x	x	x			x
C. abscondita			x	x	x	x	x	
C. laxiflora var. serrulata				x				
C. amphibola				x	x	x	x	
C. glaucodea			x	x	x	x	x	
C. prasina			x	x	x			
C. debilis			x	x	x	x	x	
C. virescens			x	x	x			
C. caroliniana				x	x	x	x	
C. riparia var. lacustris	x	x	x	x				
C. tuckermani	x	x	x	x				
C. gigantea				x	x	x	x	
Commelina diffusa				x	x	x	x	
C. virginica				x	x	x	x	
Juncus interior	x						x	x
J. diffusissimus				x	x	x	x	
*J. secundus**			x	x	x	x	x	
J. nodatus							x	
Luzula echinata**				x	x	x	x	
Stenanthium robustum				x	x		x	
Nothoscordum bivalve				x	x	x	x	x
Lilium philadelphicum var. andinum	x	x	x	x			x	x
L. superbum	x	x	x	x	x		x	x
L. canadense			x	x	x			
L. michiganense	x	x					x	x
Medeola virginiana	x	x	x	x	x			
Trillium nivale	x	x	x	x	x			
Smilax pulverulenta			x	x	x	x		
S. glauca					x	x	x	
*S. bona-nox					x	x	x	
Agave virginica				x	x	x	x	
Dioscorea hirticaulis					x			
D. glauca				x	x	x	x	
D. quaternata					x	x	x	
Iris cristata				x	x	x	x	
Habenaria peramoena				x	x	x	x	
Isotria verticillata			x	x	x	x	x	
Spiranthes beckii			x	x	x	x	x	
S. ovalis					x	x	x	
Corallorrhiza wisteriana				x	x	x	x	

TABLE II—(Continued)

	NW	N	NE	E	SE	S	SW	W
C. maculata	x	x	x	x	x			
Tipularia discolor				x	x	x		
*Hexalectris spicata					x	x	x	
Populus grandidentata	x	x	x	x	x			x
Salix interior var. wheeleri	x	x	x	x				
S. discolor	x	x	x	x	x			x
S. sericea			x	x	x			
S. tristis	x	x	x	x				x
Carya pecan							x	x
Betula lutea var. macrolepis	x	x	x	x	x			
Quercus prinus				x	x	x	x	
Q. montana			x	x	x	x		
*Q. stellata			x	x	x	x	x	x
*X Q. schuettei	x	x	x					
*X Q. fernowii					x	x	x	
Q. coccinea var. tuberculata			x	x	x	x		
Q. falcata				x	x	x	x	
Q. marilandica			x	x	x	x	x	x
Ulmus alata					x	x	x	
Celtis laevigata					x	x	x	
*C. pumila				x	x	x	x	
Phoradendron flavescens				x	x	x	x	
Commandra richardsiana	x	x	x	x				x
Asarum reflexum			x				x	x
Rumex triangulivalvis	x	x	x					x
R. brittanica	x	x	x	x				x
Polygonum arifolium var. lentiforme			x	x				
Oxybaphus nyctagineus	x						x	x
Stellaria pubera var. silvatica						x		
Sagina decumbens			x	x	x	x	x	
Silene stellata				x	x	x		
S. nivea	x	x	x	x				x
S. cucubalus	x	x	x	x				x
*Aconitum uncinatum	x			x	x			
Anemone quinquefolia var. interior	x	x	x	x				x
*Trautvetteria carolinensis				x	x	x	x	
Ranunculus pusillus**			x	x	x	x	x	
R. septentrionalis var. caricetorum	x			x			x	x
Thalictrum dasycarpum	x			x			x	x
*Magnolia acuminata			x	x	x	x	x	
Thlaspi arvense	x	x	x	x				x
Sisymbrium altissimum	x	x	x	x				x
Dentaria multifida				x	x	x		
D. diphylla	x	x	x	x	x			x
D. heterophylla				x	x			
Arabis virginica					x	x	x	

TABLE II—(Continued)

	NW	N	NE	E	SE	S	SW	W
*A. patens				x	x			
A. glabra	x	x	x	x				
*Leavenworthia uniflora						x	x	
Erysimum repandum	x			x			x	x
Conringia orientalis	x	x	x	x				x
*Sedum telephioides			x	x	x			
S. ternatum		x	x	x	x			
Saxifraga virginiensis			x	x	x			
S. pennsylvanica	x	x	x	x				x
Heuchera americana var. interior							x	x
H. americana var. hirsuticaulis								x
*H. villosa var. macrorhiza					x	x	x	
*H. parviflora var. rugellii					x	x	x	
Grossularia missouriensis	x					x	x	x
Liquidambar stryaciflua				x	x	x	x	
Physocarpus opulifolius	x	x	x	x	x			
Aruncus dioicus							x	x
Gillenia stipulata			x	x	x	x	x	
Aronia melanocarpa		x	x	x	x			
Crataegus regalis					x	x	x	
C. acutifolia							x	
*C. gattingeri var. rigida							x	
C. disperma				x				x
C. intricata			x	x	x			
*C. rubella				x	x			
*C. biltmoreana			x	x	x	x	x	
*C. prona			x	x				
C. putnamiana				x	x			
*C. incaedua							x	
*Rubus odoratus			x	x	x			
*R. enslenii	x	x	x	x	x	x		
R. centralis				x				
R. deamii						x		
R. argutus				x	x			
R. abactus	x	x	x					
Potentilla arguta	x	x	x	x				x
P. recta	x	x	x	x				x
Waldsteinia fragarioides	x	x	x	x	x			x
Geum canadense var. grimesii				x	x			
G. laciniatum	x	x	x	x				x
Prunus lanata							x	
P. hortulana						x	x	x
*Cassia nictitans var. leiocarpa				x	x			
*C. occidentalis					x	x	x	
C. hebecarpa			x	x	x			
*Cladrastis lutea					x	x	x	

TABLE II—(Continued)

	NW	N	NE	E	SE	S	SW	W
Baptisia australis			x	x	x			
Psoralea psoralioides var. eglandulosa				x	x	x	x	
Petalostemum purpureum	x						x	x
*Wisteria macrostachya						x	x	
Stylosanthes biflora			x	x	x	x	x	
*Desmodium laevigatum			x	x	x	x	x	
D. viridiflorum			x	x	x	x	x	
Lespedeza striata				x	x	x	x	
*L. nuttallii			x	x	x	x	x	
L. repens	x		x	x	x	x	x	x
L. procumbens	x		x	x	x	x	x	x
Lathyrus venosus				x				
Clitoria mariana			x	x	x	x	x	x
Galactia volubilis var. mississippiensis							x	
Phaseolus polystachus**	x		x	x	x	x	x	
Strophostyles umbellata**			x	x	x	x	x	
S. leiosperma	x						x	x
Oxalis grandis				x	x	x	x	
O. florida			x	x	x			
Linum striatum			x	x	x	x	x	
Polygala ambigua			x	x	x	x	x	
Phyllanthus caroliniensis				x	x	x	x	x
*Croton capitatus**				x	x	x	x	x
Tragia cordata					x	x	x	
Callitriche austini			x	x			x	
Evonymus americanus			x	x	x	x	x	x
E. obovatus		x	x	x	x	x		x
Acer negundo var. violaceum	x	x	x	x			x	x
Aesculus octandra				x	x	x	x	
*Rhamnus caroliniana					x	x	x	x
Vitis labrusca			x	x	x			
Ampelopsis cordata					x	x	x	x
Tilia heterophylla				x	x	x		
Hibiscus palustris**						x		
Ascyrum hypericoides var. multicaule			x	x	x	x	x	x
Hypericum ascyron	x	x	x					x
*H. dolabriforme					x			
H. drummondii					x	x	x	x
H. tubulosum				x	x	x	x	
H. tubulosum var. walteri						x	x	
*Lechea racemosula			x	x	x			
Viola cucullata			x	x	x			
V. missouriensis							x	
V. blanda	x	x	x	x	x			
Passiflora incarnata				x	x	x	x	
Rotala ramosior var. interior			x	x	x	x	x	x

TABLE II—(Continued)

	NW	N	NE	E	SE	S	SW	W
Ammania coccinea	x			x	x	x	x	x
Cuphea petiolata			x	x	x	x	x	
Decodon verticillatus**							x	
Epilobium densum	x	x	x	x				x
Oenothera tetragona var. longistipata	x	x	x	x	x			
Oe. triloba						x	x	
Aralia spinosa			x	x	x	x	x	
Sanicula trifoliata	x	x	x	x	x			
*Zizia aptera	x		x	x	x			x
*Ligusticum canadense				x	x	x	x	
Polytaenia nuttallii	x					x	x	
Cornus stricta					x	x	x	
C. obliqua	x	x	x	x				x
C. amomum			x	x	x			
*Kalmia latifolia			x	x	x	x		
*Oxydendrum arboreum				x	x	x		
Epigaea repens	x	x	x	x	x			
Gaultheria procumbens	x	x	x	x	x	x		
Gaylussacia baccata	x	x	x	x	x	x		
*Vaccinium stamineum			x	x	x			
*V. staminium var. neglectum				x	x			
*V. arboreum					x	x	x	
Hottonia inflata			x	x	x	x	x	
Lysimachia nummularia	x	x	x	x				x
L. longifolia	x	x	x	x				x
Centunculus minimus	x				x	x	x	x
Obolaria virginica				x	x	x	x	
*Gentiana villosa				x	x	x	x	
Apocynum sibiricum var. farwellii			x					
Acerates hirtella		x					x	x
Asclepias perennis					x	x	x	
A. variegata			x	x	x	x	x	
Gonolobus obliquus				x	x	x	x	
Cuscuta glomerata	x	x				x	x	x
Convolvulus spithamaeus	x	x	x	x	x			
C. sepium var. fraterniflorus	x						x	x
C. repens			x	x	x			
Ipomoea lacunosa				x	x	x	x	x
Quamlocit coccinea			x	x	x	x	x	
Phlox amplifolia						x	x	
P. ovata				x	x			
P. glaberrima	x				x	x	x	x
P. pilosa var. amplexicaulis					x	x	x	
P. bifida	x	x				x	x	x
Hydrophyllum canadense	x	x	x	x	x			
Cynoglossum virginianum			x	x	x	x	x	

TABLE II—(Continued)

	NW	N	NE	E	SE	S	SW	W
Lithospermum incisum	x						x	x
Verbena canadensis					x	x	x	x
V. urticaefolia var. leiocarpa			x	x	x			
Scutellaria nervosa				x	x	x	x	x
S. australis						x	x	
*S. saxatilis				x	x	x	x	
Synandra hispidula				x	x			x
Stachys riddellii				x	x			x
S. clingmani					x			x
Salvia lyrata			x	x	x	x	x	
Monarda clinopodia			x	x	x			
Satureja vulgaris	x	x	x	x				
Pycnanthemum pycnanthemoides				x	x			
*P. incanum			x	x	x	x	x	
*Cunila origanoides			x	x	x	x	x	
Lycopus uniflorus	x	x	x	x	x			
L. americanus var. longii			x	x				
Perilla frutescens var. crispa			x	x	x	x	x	
*Physalis nyctaginea			x	x	x	x		
P. pruinosa			x	x	x			x
Kickxia elatine**							x	
Chaenorrhinum minus	x	x	x	x				x
Collinsia verna	x	x	x	x	x		x	x
Chelone obliqua var. speciosa							x	x
C. glabra var. elongata				x	x	x		x
C. glabra var. linifolia	x	x	x	x				x
*C. glabra var. elatior				x	x	x		
Penstemon alluviorum				x	x	x	x	
P. deamii							x	
P. canescens				x	x	x		
Hydranthelium rotundifolium						x	x	x
Gerardia tenuifolia var. parviflora	x	x	x				x	x
Bignonia capreolata					x	x	x	
Conopholis americana			x	x	x			
Ruellia caroliniensis var. parviflora				x	x	x	x	
Dicliptera brachiata var. glandulosa					x	x	x	
Plantago pusilla	x						x	x
Houstonia nigricans					x	x	x	
Diodia teres var. setifolia			x				x	
*Galium circaezans			x	x	x	x	x	
G. lanceolatum	x	x	x	x	x			
*G. parisiense					x	x		
Viburnum rufidulum				x	x	x	x	
V. pubescens var. deamii						x		x
V. pubescens var. indianense				x				
Triosteum aurantiacum	x		x	x				x

TABLE II—(Continued)

	NW	N	NE	E	SE	S	SW	W
T. aurantiacum var. illinoiense				x			x	
T. angustifolium			x	x	x		x	
Lonicera japonica			x	x	x			
L. dioica var. glaucescens	x	x	x	x	x			
L. prolifera	x	x	x	x	x			
Dipsacus sylvester			x	x	x			
*Melothria pendula				x	x	x	x	
Echinocystis lobata	x	x	x	x	x		x	x
Lobelia puberula				x	x	x	x	x
Elephantopus carolinianus				x	x	x	x	x
*Eupatorium incarnatum					x	x	x	
*Solidago erecta				x	x	x		
*S. squarrosa			x	x	x			
S. canadensis	x	x	x	x	x			
S. canadensis var. gilvocanescens			x	x				x
S. sphacelata				x	x	x		
*S. ovata (endemic)								
S. riddellii	x	x	x	x				
Aster paniculatus	x	x	x				x	x
A. lateriflorus			x	x	x			
A. vimineus			x	x				
*Sericocarpus linifolius			x	x	x	x	x	
Antennaria neglecta	x	x	x	x				x
A. neodioica	x	x	x	x				
*A. solitaria				x	x	x	x	
A. parlinii	x	x	x	x	x			x
A. fallax	x	x	x	x		x	x	x
A. fallax var. calophylla				x	x	x	x	
Anaphalis margaritacea var. intercedens	x	x	x	x				x
Polymnia uvedalia			x	x	x	x	x	
Silphium trifoliatum			x	x	x			
S. trifoliatum var. latifolium				x	x	x		
Ambrosia bidentata							x	x
*Rudbeckia fulgida			x	x	x	x	x	
R. umbrosa					x	x		
Helianthus rigidus	x						x	x
Verbesina helianthoides				x	x	x	x	x
Bidens coronata	x	x	x	x	x			
Helenium nudiflorum			x	x	x	x	x	
Dyssodia papposa	x						x	x
Senecio glabellus					x	x	x	
*Cirsium virginianum					x	x	x	
Krigia dandelion				x	x	x	x	x
Tragopogon pratensis	x	x	x	x				x
Lactuca canadensis var. obovata			x	x			x	x
Hieracium paniculatum		x	x	x	x	x		

A STUDY OF SOME FACTORS AFFECTING ASYMMETRICAL GROWTH OF TREES

By MATTHEW H. HARMON

Observations on stumps left by lumbering operations show that in many cases the organic center of the stump is far removed from the geometric center. This led into an investigation of factors causing asymmetrical growth of trees. As there has been but little research on unsymmetrical growth, little light has been thrown upon the subject by a perusal of the literature. Friesner (5) states that unsymmetrical growth is due to a combination of factors, some internal and some external, of which location of spreading roots, itself determined partly by internal and partly by external factors, variation in slope and other soil relations, and competition with other trees are the most likely. Glock (6) states that fluctuations in width of an individual ring on different radii of the same year ring is probably influenced by root activity. Areas of wide growth have a greater tendency to cluster about certain radii near the base of the stem than they do farther up the trunk of the tree. Cooper (3) states that in layering branches of Sitka spruce and two western hemlocks, asymmetrical growth is due to production of adventitious roots resulting in increase in the water supply. This stimulates wood growth on the side receiving the greatest supply of water, thus contributing to asymmetrical growth. Brown (2) says that uneven growth in width of the rings is affected directly by the amount of conducting tissue. The amount of conducting tissue in the trunk is proportionate to the conducting tissue in the roots. Thus, if one root has a large supply of conducting tissue there will also be a large amount of conducting tissue directly above that root in the trunk. Auchter (1) has shown that mineral salts absorbed by a root in one vertical zone of a tree are primarily used in that same zone and not laterally distributed to any great extent. Lodewick (7) working on the longleaf pine of Florida found that there is little relation between unequal crown and amount of growth in radical directions in the vertical zones beneath the crown variations.

METHODS AND MATERIALS

Cores were obtained by use of a Swedish increment borer from standing trees of *Quercus borealis, Q. alba, Q. shumardii, Q. mon-*

tana, Q. velutina, Fraxinus americana, Carya glabra, C. ovata, Acer saccharum, Platanus occidentalis, Liriodendron tulipifera and *Populus grandidentata.* The cores were taken between 75-115 cm above the surface of the soil and upon removal from the borer they were glued into rabbited pine blocks, numbered and taken to the laboratory for measurement of annual growth. Around the trees from which cores were taken, all other trees within a radius of 35 feet from the sample tree were measured and carefully located by means of a tape measure and compass on polar graph paper. The earth was dug away from the base of each tree so as to expose main spreading roots and their location was also plotted on polar graph paper.

The trees selected for boring were chosen from predetermined environmental groups which appeared to have one outstanding factor unequally affecting the growth of the tree. The factors were as follows: 1) Trees growing close enough together that competition must be one of the most important factors in their growth and must affect the tree unequally on different vertical zones. 2) Relation between tree and position in the soil, i. e. trees directly on ravine bank or trees on gentle slopes. 3) Trees located so as to be affected by moisture, i. e. trees located on the bank of permanent streams, containing water the year around, and trees located on the bank of streams that contain water only during the wet season of the year. 4) Trees showing well developed root systems.

Cores were taken so as to show the following factors which may affect growth: 1) along radii which were vertically above the main spreading roots and along other radii which were between these roots. 2) Along radii which divided the up-hill and down-hill side of trees. 3) Along radii that if extended would intercept trees near enough to appear to cause root competition. All cores were of sufficient length to pass through the geometric center of the trees. All holes left by the borings were plugged with grafting wax.

Measurements of cores were made under low power of a binocular microscope with a ruler divided into 0.5 mm. Thus measurement could be made accurately to the nearest 0.25 mm. Cores before being measured were trimmed with razor blades so as to present a flat surface, thus making the year rings stand out much more clearly.

EFFECT OF ROOTS ON ASYMMETRICAL GROWTH

In the present study cores were taken in zones directly above the main spreading roots and between such roots. From table I it will be seen that the average growth along radii above roots is greater than that above spaces between roots in only 9 out of the 16 trees used. The longest radius in each individual tree occurred in a zone vertically above a spreading root in 12 of the 16 trees, the other 4 having their longest radius in a vertical zone above the space between roots. The shortest radius of each individual tree occurred in a zone above the space between roots in 11 of the 16 trees, the other 5 having their shortest radius above roots.

These results appear to be in conflict to a considerable degree with those of Friesner (5). Two important differences between the present work and that of Friesner make it difficult to ascertain precisely how much conflict there is in results. (1) The present paper deals with 8 species of trees only two specimens of which were *Q. velutina*, whereas the former paper was based entirely on the latter species. (2) Present results are from borings 15-115 cm above the soil while the former paper dealt with sections cut from the tops of stumps 30-40 cm from the soil. It is to be expected that the effect of root location upon growth will be greater the nearer the material studied is to the roots themselves. Since the cores used in the present study are approximately 3 times as far from the roots the relationship should be expected to be less distinct. It should also be borne in mind that radii measured from cut sections can follow medullary rays and hence be true "organic radii" whereas those measured from borings are "geometrical radii" but not necessarily "organic radii."

RELATION OF SLOPE TO UNSYMMETRICAL GROWTH

It has been shown by Douglass (4) that slope affects eccentric growth in Western pine when slope is such that it makes water available earlier on one side of the tree than the other. Table II shows the relation of slope to eccentric growth. Out of 11 trees growing on gentle slopes, 7 showed greater growth on the downhill side. Of these 7 trees, 6 had the same number of spreading roots on both the uphill and downhill slope. In tree no. 35 growth occurred on the side of the tree having the most roots. This was the downhill side of the tree. In 4 trees showing greatest growth on uphill side of tree, two of them (11 and 14) did have more roots on the uphill side of the tree than on the downhill side. Of the other two trees, one (no. 24) had more roots on the downhill side of the tree but showed greater growth on the uphill side. Tree no. 36, however, had the same number of roots on both sides of it, yet this tree grew most on the uphill side. However, when differences in growth on both slopes is averaged, more growth appears on the uphill slope. This difference is so little, only 0.23 mm per radius, that no importance may be attached to it. The conclusion may be drawn that slope variations give no dependable relationship to eccentric growth although there is some evidence to show that on gentle slopes the downhill side of the tree will be favored at the expense of the uphill side.

Ten trees on the edge of a ravine bank were selected for study. The data are in table II. Of these 10 trees, one tree (no. 6) apparently was not affected by its location. It grew the same amount on both the bank and the brink side of the tree. There was an equal number of roots present on each side. However, in 5 other trees (nos. 10, 13, 31, 5 and 7) more growth occurred on the bank side of the trees. The 5 trees each had, however, greater number of roots on the brink side than on the bank side. This may only be apparent and not real, due to better chance to observe roots on the brink side. In 4 remaining trees (nos. 34, 26, 33 and 32) growth occurred more on the brink side of the tree than on the bank side. Tree no. 32 had the same number of spreading roots on both sides of the tree. Tree no. 26 had more roots on the bank side but grew more on the brink side. In trees no. 34 and 33 the spreading roots were too deeply located to be plotted and observed. However, these two trees also showed greatest growth on the brink side of the tree. From this study of trees located on ravine bank, the conclusion can be drawn that slope variations do not give a dependable relationship to eccentric growth.

EFFECT OF COMPETITION ON ECCENTRIC GROWTH

Four trees growing in such a position that competition must have affected them were chosen for this study. All were *Liriodendron tulipifera*. Trees no. 19 and 20 were but six feet apart, each was 17.5 inches DBH. and was located on a gentle slope. No. 28 and 29 were four feet apart and were 13 and 11 inches DBH. respectively. They were located in a forest dominated by *Fagus grandifolia* ranging from 18 to 30 inches DBH. which were fairly evenly spaced 25-75 feet apart. Table III shows the competition data. The competition side of tree no. 19 was uphill. Average growth of radii no. 1, 2, and 3 is 162.9 mm, while the non-competition side showed an average growth of 181.66 mm. This was 29.3% more growth on the side without competition. Tree No. 20 had an average growth of 149.5 mm on the competition side and 156 mm on the side without competition. This was 4.59% greater growth on the side without competition. Tree no. 28 had an average growth of 168 mm on the side with competition, the non-competition side having an average of 232.66 mm which is 38.49% greater growth on the non-competition side of the tree. Tree no. 29 had an average growth of 237.33 mm on the competition side and an average of 147 mm on the non-competition side. This is 91% greater growth on the competition side. Thus in three of the four trees (no. 19, 18 and 28) the side of the tree having competition showed 4.59-38.40% less growth than the non-competition side (table III). Tree no. 29 must have been influenced much more greatly by some factor other than competition since this tree grew more every year on the competition side of the tree than on the non-competition side. In these trees of *L. tulipifera* the side away from competition, if not influenced by some other controlling factor, grew more than the side with competition thus leading to unsymmetrical growth. The factor that controlled growth in tree no. 29 is believed to be that of water content of the soil. This study shows that competition as a factor may influence unsymmetrical growth but that it is easily overshadowed by other controlling factors.

Table IV presents data showing the effect of competition at different age periods of these trees (*L. tulipifera*). It will be observed that competition was effective for a larger number of "radius-years" during the second and third 10-year periods in tree no. 19 whose borings comprised 58 years of growth per radius; during the third and fourth 10-year periods in tree no. 20 whose borings showed 52 years of growth per radius; and during the first 10-year period in tree no. 28 whose borings showed 30 years of growth.

EFFECT OF WET-WEATHER STREAMS

Table V shows data of trees growing on banks of streams that were carrying water only during the rainy season of the year. In three out of four trees studied, more growth occurred on the bank side of the tree, i. e. the side where roots were farther from the stream, but tree no. 2 grew more on the stream side. Similar behavior occurred in tree no. 1 which also grew more on the stream side. Tree no. 1 however grew on the bank of a stream containing water the year around. On the basis of these data it appears that trees growing on the banks of streams that contain water only in the rainy season grow more on the bank side than on the stream side of the tree. This is most likely due to the presence of fewer roots in soil along the stream side, together with a more uniform supply of soil water on the bank side. Also in the rainy season of the year there would be a surplus of water which would saturate the ground, making for bad aeration and leaching minerals out of the ground thus causing growth to be retarded on the stream side. Due to this surplus water, roots on the stream side are apt to become shallow as the most favorable growing season is in spring when this surplus water occurs. The roots would tend to become water logged thus again retarding growth. This shallowing of roots in spring would be reflected in the summer growth as it would not permit roots to be deep enough in the ground to obtain a plentiful supply of water and salts during drier seasons. This would result in decreased supply of water and salts on the stream side of the tree with a resulting decrease in growth on that side. Roots on the stream side of trees would be more likely to be damaged by washing of water in wet-weather streams and their tissues would be torn by the movement of rocks and debris of the stream. This would not be so apt to occur in permanent streams since there is an even current rather than a swift destroying current of the wet-weather streams.

DISCUSSION

Of many factors that show any demonstrable relation to unsymmetrical growth, position of main spreading roots, slopes and competition are the 3 most evident. In this study it was found that in most cases trees which had main spreading roots on the downhill side of the tree grew most on this side. From this the conclusion may be drawn that slope plus root location combined play a most important role in eccentric growth. Slope alone, if only gentle, plays but a small role in unsymmetrical growth. Greater growth tends to be on the downhill side of the tree on gentle slopes. However, if the slope is steep, such as on the banks of a ravine, growth appears to be greater on the uphill side. It is possible that the reason growth is greater on the downhill side of the tree on gentle slopes is because of leaching of mineral salts downward on the slope thus making for a greater concentration toward the bottom of the slope. The water table would be higher, too, at the foot of the slope than at the top. Thus the trees would tend to send more roots downhill because of greater available water supply and mineral salt concentration.

This would tend to permit greater passage of salts and water on the downhill side of the trees thereby permitting more growth on this side of the trees.

On the other hand, trees growing on a steep slope, ravine brink, or bank of temporary stream are more likely to be able to have a more adequate root supply on the uphill side (due to erosion) than on the downhill side. This should be reflected in greater growth on the uphill side. This is borne out by results shown in table II.

It was found that trees growing off streams that contain water only in the rainy season show the most growth on the side away from the stream. These trees may have the same number of spreading roots on each side and still this holds true.

Competition was another factor studied in this experiment. Weaver and Clements (8) state that competition between species of the same kind is strongest. In trees studied it was found that growth was less on the competition than on the non-competition side. This was probably due to the fact that roots on the competition side of two trees were constantly competing with each other for space in the soil, for nutrients and, probably most important of all, for water. However if one of the competing trees is favored by some additional factor more than the other as in the case of trees no. 28 and 29, then the competition factor may be offset. Judging from the site, tree no. 29 received more water on its competition side than it did on its non-competition side. If this is true, it would account for the fact that of four trees studied this was the only one showing more growth on the competition side than on the non-competition side. Another factor of competition is light. In this experiment two of the competing trees were but 4 feet apart and the other two were but 6 feet apart. This would be likely to affect the leaf and its activity by making fewer branches and fewer leaves and, hence, less food on the competition side.

Asymmetrical growth is due to a combination of many factors of which no one can be said to be directly responsible. However, of these factors some are more important than others. The factors that show the greatest response in unsymmetrical growth are probably root position, slope and competition. Of these three factors, root position combined with slope is the most important.

SUMMARY

1. Cores were obtained from standing trees showing differences

in the following factors: 1) root position, 2) competition, 3) slope, 4) banks of streams containing water only in the rainy season and 5) ravine banks.

2. Average growth per radius is greater in vertical zones above roots in only 50% of the trees studied, but total growth above roots when all trees are considered is greater than total growth between roots.

3. Gentle slope as a part of a complex of factors usually favors the downhill side of the tree in unsymmetrical growth.

4. Very steep slopes such as a ravine brink affects unsymmetrical growth in that growth is less on the brink side of the tree than on the bank or uphill side of the tree.

5. Competition when not offset by other factors exerts a demonstrable influence upon asymmetrical growth in that growth on the competition side is less than on the non-competition side of trees. This is correlated with greater root supply on the non-competition side of trees.

6. Trees standing on the banks of temporary streams usually show greater growth on the side away from the stream.

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TABLE I

Relation between growth along radii which center on main spreading roots and those which come between such roots. Figures are averages of all radii of each type for each tree.

Tree		Radii on Roots Number of Radii	Growth	Radii off Roots Number of Radii	Growth
Q. velutina	8	4	264.21 mm	3	276.58 mm
Q. velutina	32	3	188.66	3	226.58
Liriodendron	11	4	276.43	4	287.31
Liriodendron	12	4	152.27	4	162.06
Liriodendron	13	3	156.62	3	148.12
Liriodendron	21	3	154.09	3	148.19
Acer saccharum	15	4	77.21	4	80.65
Acer saccharum	24	3	93.75	3	90.50
Carya ovata	16	4	171.31	4	154.12
Carya ovata	22	4	99.15	4	102.72
Q. alba	18	4	156.40	4	164.59
P. grandidentata	23	4	116.53	4	121.55
P. grandidentata	26	4	103.90	4	102.31
P. grandidentata	27	4	165.15	4	149.78
Q. borealis	38	4	90.66	4	88.75
Platanus occidentalis	35	5	218.52	3	168.29
Total			2484.76		2471.10

TABLE II

Effect of slope on unsymmetrical growth. Figures are average growth per radius.

Tree		Uphill Number of spreading roots	Average Growth	Downhill Number of spreading roots	Average Growth
		A. Gentle Slope			
L. tulipifera	14	2	133.33 mm	1	109.00 mm
Acer saccharum	15	2	74.28	2	83.84
Carya ovata	16	2	163.46	2	164.25
Q. alba	18	2	148.75	2	167.62
L. tulipifera	21	2	155.83	1	146.58
Carya ovata	22	1	95.12	1	107.12
P. grandidentata	23	1	118.58	1	125.62
Acer saccharum	24	1	103.39	2	97.50
Q. shumardii	35	2	165.86	3	200.45
Q. borealis	36	2	189.42	2	158.00
Q. borealis	38	2	86.90	2	91.33

TABLE II—(Continued)

Tree		Uphill Number of spreading roots	 Average Growth	Downhill Number of spreading roots	 Average Growth
		B. Ravine Brink			
Q. montana	5	3	192.65	4	97.50
Q. borealis	6	2	85.00	2	85.00
Q. velutina	7	3	280.00	5	170.80
L. tulipifera	10	1	110.50	2	53.80
L. tulipifera	13	2	175.00	3	142.65
P. grandidentata	26	3	102.70	1	109.00
P. grandidentata	31	0	91.50	0	89.00
Q. velutina	32	2	101.80	2	105.50
Q. montana	33	0	43.80	0	61.80
Carya glabra	34	0	82.00	3	89.15

TABLE III

Relation between growth along radii with and without competition with other trees.

Tree No.	Radius	Competition Description	Growth	Radius	Non-competition Description	Growth
19	1	17.5" Liriodendron, 6' away	163.00 mm	4	opposite radius 1	185.25 mm
	2	same	146.60	5	opposite radius 2	180.87
	3	same	179.00	6	opposite radius 3	178.87
		Average	162.90		Average	181.66
20	4	18" Liriodendron, 6' away	128.50	1	opposite radius 4	136.00
	5	same	163.50	2	opposite radius 6	160.50
	6	same	156.50	3	opposite radius 5	171.50
		Average	149.50		Average	156.00
28	1	11" Liriodendron, 4' away	151.00	4	opposite radius 1	228.00
	2	same	152.00	5	opposite radius 2	294.00
	3	same	176.00	6	opposite radius 3	173.00
		Average	168.00		Average	232.66
29	4	13" Liriodendron, 4' away	259.00	1	opposite radius 4	115.00

TABLE III—(Continued)

Tree No.	Radius	Competition Description	Growth	Radius	Non-competition Description	Growth
	5	same	269.00	2	opposite radius 6	139.00
	6	same	214.00	3	opposite radius 5	187.00
		Average	237.33		Average	147.00

TABLE IV

Effect of competition on each ten years of life of tree. Percentages are for the average number of years that growth was greater on the non-competition side of the tree than on the competition side.

Tree No.	First 10-Yr. Period	Second 10-Yr. Period	Third 10-Yr. Period	Fourth 10-Yr. Period	Fifth 10-Yr. Period
19	60%	90%	80%	60%	50%*
20	30	50	80	70	100 **
28	90	60	60		
29	0	0	0 ***		

* Only 8 years of growth.

** Only 2 years of growth.

*** Competition side showed 100% greater growth every year than non-competition side of tree.

TABLE V

Effect of position of banks of streams on eccentric growth. Four of the trees were located on edge of stream carrying water only in rainy season. Growth figures are averages per radius.

Tree No.		Bank Side Radii Counted	Bank Side Growth	Stream Side Radii Counted	Stream Side Growth
Q. alba	2	3	120.83 mm	3	125.33 mm
Platanus	25	3	114.50	3	111.33
Platanus	30	3	107.33	3	105.33
Liriodendron	39	3	191.50	3	122.16
Fraxinus	1*	3	110.16	3	111.33

* On bank of permanent stream.

VERTICAL GROWTH IN FOUR SPECIES OF PINES IN INDIANA

By RAY C. FRIESNER

The time and character of height growth in conifers has been studied by several American investigators but, so far as is known to the writer, these studies have included only two species of pines and all have been done in New York or New England States. These previous studies have included the following areas and species: *Pinus resinosa*, New York, Baldwin (1), Cook (2), Tryon and Finn (6); Connecticut, Kienholz (4); New Hampshire, Kienholz (3); *Pinus strobus*, Connecticut, Stevens (5). Since an opportunity was afforded on the author's own plantings in Brown County, Indiana, to study these two species and *Pinus sylvestris*, in addition; and to study an additional species, viz. *P. banksiana*, on the nearby plantings of Mr. Charles Youngman, it was thought worthwhile to present these data on these additional species and on species previously studied but from a very different geographical area. The work of Cook (2) and Kienholz (4) were published several months after the present work was well under way and did not come to the writer's attention until after the present data were complete.

METHODS

On March 22, 1941, 50 specimens each of *Pinus strobus*, *P. resinosa*, *P. sylvestris* and *P. banksiana* were selected for study. The lengths of the terminal bud, the height, and the approximate age of each tree was noted and each was marked by a number inscribed with India ink on a linen tag. The approximate age of each species except *P. banksiana*, was determined by counting the number of annual "internodes" of growth present. These trees showed from 3 to 8 "internodes" of growth. The individuals of *P. resinosa* and *P. sylvestris* were transplanted in April, 1936, while those of *P. strobus* were of two lots, one transplanted in April, 1936, and the other in April, 1938. The individuals of *P. banksiana* were transplanted in April, 1938. It is thus apparent that all specimens had become well established. At the beginning of the observation period the specimens of *P. strobus* showed a height range of 19-312 cm; the range for *P. resinosa* was 56-178 cm, that for *P. sylvestris* was 77-294 cm, and for *P. banksiana* it was 71-154 cm.

Measurements were made by sliding a short arm attached at right angles on a vertical millimeter scale, the bottom of the latter resting each time on a rust-proof pin which completely pierced the stem within the level of the topmost false whorl of lateral branches. The upper limit of measurement was the tip of the growing point of the twig and, as soon as it was formed, the tip of the terminal bud containing the next year's primordia. Measurements were taken weekly from March 31 to October 16 and a final one on December 4, 1941. All were made to the nearest mm.

All specimens except those of *P. banksiana* were on a hillside with gentle to moderate slope and with north, west, and northwest exposure. Those of the latter species were on a nearly level site on top of a ridge. The entire area belongs to the so-called Knobs area of Indiana. This area is characterized in its native condition by *Quercus alba, Q. velutina, Q. montana, Carya ovata, C. glabra* and *C. ovalis.*

The area receives an average-expected annual rainfall of 40.46 inches. That for the year during which the measurements were taken was 32.80 inches which is 81.07% of the normal-expected for this area. From table I it will be seen that rainfall for the first 5 months of the year 1941 was much below the normal-expected. Not until June, when most of the growth in most of the specimens was over, did rainfall exceed the usual. The site is approximately 1,100 feet above sea level.

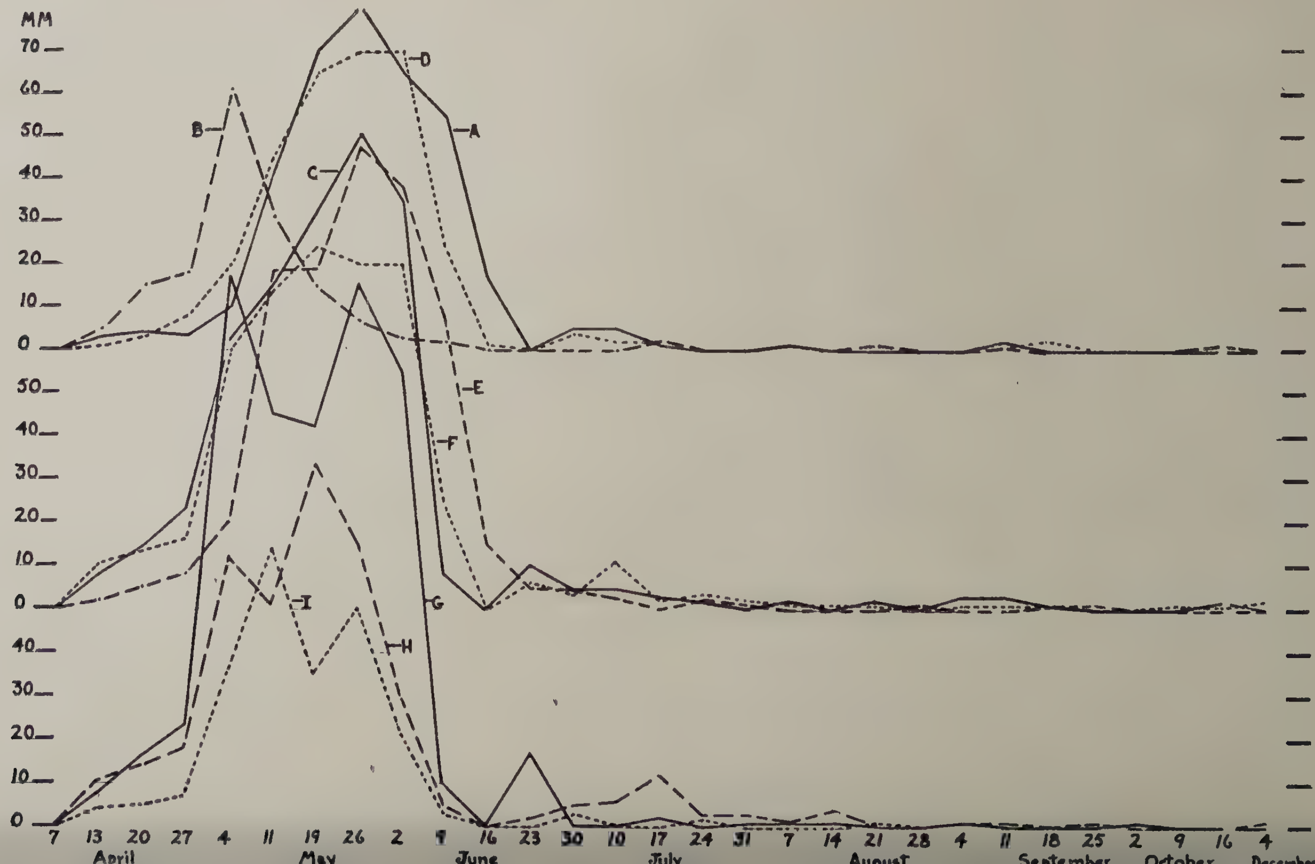
RESULTS

CHARACTER OF ELONGATION CURVES

Vertical growth was begun by all species during the week ending April 13. From table II it will be seen that every individual of *P. banksiana,* 82% of *P. sylvestris,* 96% of *P. resinosa* and 30% of *P. strobus* began growth during this week. The majority (66%) of individuals of *P. strobus* and 16% of *P. sylvestris* began the following week while two individuals of *P. strobus* and one of *P. sylvestris* were delayed until the third week.

Individual curves were plotted showing the course of the growth activity for each of the 200 trees studied. A careful survey of these curves showed that they fall into 9 different types, one each of which is shown in curves A to I inclusive in figure 1. These curve types may be characterized as follows:

Curves of type A (fig. 1) are essentially symmetrical, i. e. after one or two weeks of slower growth they rise steeply to a maximum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August
September
October
December

and then decrease in a very similar, except inverse, order to the midsummer zero. All curves of all types show somewhat oscillating small amounts of elongation for a number of weeks following the midsummer zero period. This will be discussed after the character of the main growth has been disposed of. Curves of type A are not frequent. Table III gives the frequency of the various types of growth curves exhibited by these four species of pines and there it will be noted that curves of type A occur in 6 individuals of *P. resinosa,* 3 of *P. sylvestris,* 1 of *P. banksiana* and none of *P. strobus.* This makes a total of but 5% of all of the curves.

Curves of type B (fig. 1) differ from those of type A primarily in that there is a less conspicuous initial drag, the curve rises more steeply to the peak and descends less rapidly and over a longer period of time to the midsummer zero point. Curves of type B are thus steeper on the left than on the right. This type of curve is somewhat more frequent than type A and occurs (table III) in 3 individuals of *P. strobus,* none of *P. resinosa,* 7 of *P. sylvestris,* and 9 of *P. banksiana* making a total of 9.5% of all individuals measured. It is worthy of note that, while this is the type of curve shown for *P. resinosa* by Kienholz (4), it is not exhibited by a single individual of this species in the present study. The curve shown by Kienholz, however, is not one for a particular individual but a curve obtained by averaging a number of individuals over a period of years.

Curves of type C (fig. 1) are similar to those of type B except that they are the reverse of each other, i. e. those of type C present a much more rapid decline from the peak of most rapid elongation to the midsummer zero than the rise from initiation of growth to the peak. Curves of type C are thus much steeper on the right while those of type B were steeper on the left. Curves of type C are much more frequent in *P. strobus* and *P. resinosa* than in any other species and are also more frequent in these two species than any other types of curves are in these same species. In table III it will be seen that curves of type C occur in 15 (30%) individuals of *P. strobus,* 22 (44%) of *P. resinosa,* 3 (6%) of *P. sylvestris* and none of *P. banksiana.* This makes a total of 20% of all individuals of all four species. Apparently this same type of curve was exhibited by *P. resinosa* in the results of Cook (2).

In curves of type D (fig. 1) the peak of elongation is maintained at a nearly uniform rate for 2 or, in some cases, 3 weeks, thus giving the curve a flat top. These curves are similar to those of type C in that they are steeper on the right than on the left. This type of curve is found most frequently in the same species where the preceding one is found, viz. *P. strobus* (12 individuals) and *P. resinosa* (10 individuals, table III). In spite of the fact that these individuals show a sustained peak they do not, on the average, show a greater total growth than individuals exhibiting other types of curves.

Curves of type E (fig. 1) show a temporary pause in the rate of acceleration of elongation and thus exhibit a flat place (plateau) somewhere near the peak on the left side. In these individuals some unknown internal factors result in a temporary failure of the regular weekly increase in growth rate after which the rate speeds up and continues to the maximum rate. Curves of this type are found (table III) in 4 individuals of *P. strobus*, 2 of *P. resinosa*, 3 of *P. sylvestris* and are absent in *P. banksiana*.

Curves of type F (fig. 1) differ from those of type E in that the flat place or plateau is on the right or descending side of the curve. These curves result from a temporary holding of a rate of growth for a second week at a higher point for this second week than would have been expected in the light of what this individual had been doing. This type of curve is found (table III) in 3 individuals of *P. strobus*, 1 each of *P. resinosa* and *P. sylvestris* and 2 of *P. banksiana*.

Curves of type G (fig. 1) exhibit a double peak in elongation rate, the 2 peaks being of about equal intensity. Such a curve is an indication that the individual had elongated at a rate which temporarily exceeded the ability of internal factors to support it but after a period (usually 1 week) of deceleration these factors gained new momentum sufficiently to restore the elongation to a rate equal in intensity to that of the first peak. These curves are rare, occurring (table III) in only one individual each of *P. strobus*, *P. resinosa*, and *P. sylvestris*.

Curves of type H (fig. 1) also show two peaks of elongation but differ in that they are not of equal intensity. After the first peak is reached there is a temporary slowing followed by a new acceleration which continues to a peak higher than that previously reached. This type of curve was found (table III) in 6 individuals of *P. strobus*, 6 of *P. resinosa*, and 4 of *P. sylvestris* but was absent from *P. banksiana*; thus occurring in 8% of all individuals studied.

Curves of type I (fig. 1) are similar to the last 2 mentioned in that they exhibit double peaks of elongation rate but differ in that the higher peak is reached first and the lower peak occurs as a temporary increase during the time of decelerating growth. This is the predominating type of curve in both *P. sylvestris* and *P. banksiana*, occurring (table III) in 27 individuals of the former and 38 of the latter species. It thus occurs in 54% and 76% respectively of the individuals studied in these species. This type of curve was also found in 6 individuals of *P. strobus* and 2 of *P. resinosa*.

TIME OF MAXIMUM ELONGATION

Table IV presents the data regarding the time of the peak in elongation rate. Individuals exhibiting more than one peak are shown for the date upon which the highest peak occurred. It will be noted that every one of the individuals of *P. banksiana* reached their highest peak during the week ending May 4 which, in every case, is 4 weeks after elongation began (cf. tables II and IV). While these trees all reached their peak in growth rate within 4 weeks it should also be noted that 76% of them (table III) exhibited a second but somewhat lower peak after the first one occurred.

The majority of *P. sylvestris* (74%, table IV) also reached their peak of elongation rate during the week ending May 4 which was, for most of them, 4 weeks after initiation. Initiation of elongation occurred in 82% of the individuals (table II) during the week ending April 13, but only 74% reached their peak in rate within the 4-week period. The majority of individuals showing this 4-week period of acceleration (27 out of 37) showed a second but lower peak following the primary one. While the majority of the individuals showed the short (4-week) period of acceleration of elongation, 18% showed a longer period reaching their peak during the week ending May 26. These were for the most part individuals which began elongating during the week ending April 20 (table II and IV) and hence have used 6 weeks in reaching their peak in rate.

Pinus resinosa in every instance used a longer period of time for its acceleration of elongation. In table IV it is noted that 60% of the individuals reached their maximum rate during the week ending May 26 and 28% reached it during the preceding week. It is thus apparent that 6-7 weeks elapsed for most of these individuals, and even 8 weeks for some, between initiation and maximum rate of elongation since 96% of them (table II) began during the week ending April 13. Kienholz (4) shows 6 weeks in his "average" curve for this species. Kienholz found the peak in elongation rate for this species to come during the week ending June 10 at Keene (3) and May 30 in Connecticut (4) while Tryon and Finn (6) found it to occur late in May at about the same time for each of three consecutive years in New York.

Pinus strobus shows a greater variability both in time of initiation and time of maximum rate of elongation than is shown for the other species studied. Initiation occurred (table II) for 30% during the week ending April 13, for 66% during the following week and for the remaining 4% another week later. Maximum rate occurred for the various individuals over a spread of 5 weeks with 6% reaching it during the week ending May 4 (table IV) and 18, 14, 38 and 24% reaching it for successive following weeks. The time elapsed thus varied from 4 to 7 weeks. Stevens (5) found the maximum in rate of elongation for this species to come about June 10 for 1928, '29 and '30 at Keene.

Comparison of these data (table IV) with rainfall for the months preceding and during the period of accelerating growth (table I) may throw some light upon both the elapsed time and the double peaks shown in curves of type I (table III). It will be noted in table I that rainfall throughout the first 5 months of the year 1941 was far below the normal-expected for this area. Only during the months of April and May did the rainfall approach even 50%. The total rainfall for the 5-month period was only 35.94% of the normal-expected. Abundance of rain came in June when 181.23% of the normal-expected fell but this was after both primary and secondary maxima in elongation rate were reached in every individual. These June rains had no part in the secondary maxima reached by 54% of the individuals of *P. sylvestris*, and 76% of those of *P. banksiana* (table III) since all were over before the rains came. The small amount of rainfall during April and, more particularly during May, may have brought the maxima in elongation rate earlier than would have been the case if more water had been available but it is more probable that its effect had more to do with the total amount of elongation.

THE MIDSUMMER PAUSE

Elongation rate in all individuals declined from the maximum to zero or near-zero. This zero-point was reached for the majority of all species during the 2-week period ending June 23 (table V). It was reached during the week ending June 16 by more individuals than during the following week but the total time-spread necessary for all individuals to reach it was 7 weeks. The time elapsed between the maximum in elongation rate and the midsummer zero-point was 4-9 weeks for *P. banksiana,* 4-7 for *P. sylvestris,* 3-7 for *P. resinosa* and 3-6 for *P. strobus.* By comparing table IV and V it will be seen that the first individuals to reach the midsummer zero are doing so by the time the latest ones reach their peak in elongation rate. It should also be noted that the zero point is reached by the majority of individuals at the very time when available water is the most abundant.

The time elapsed between initiation of elongation and the midsummer pause is shown in table VI where the number of individuals showing each elapsed amount of time is shown in relation to starting height of the tree. It will be noted that from 7 to 12 weeks elapsed between initiation and midsummer pause in *P. strobus* with the majority of the individuals continuing elongation 8-10 weeks. In *P. resinosa* the time is 8-10 weeks with the majority using 9 weeks. Kienholz (4) found this time to average 60 days at Keene, N. H., and Baldwin (1) found it to be 69 days at Ithaca, N. Y., while Cook (2) found it to vary from 45 to 63 days over a 5-year period near Stephentown, N. Y. In *P. sylvestris* the elongation period varied from 8 to 12 weeks with the majority using 8-9 weeks while in *P. banksiana* the time is 7-12 weeks with the majority using 8-10. Table VI shows no detectable relation between amount of time used for elongation and height-classes of trees nor is there any apparent correlation between the time of initiation of elongation and the length of time during which it will continue.

ELONGATION FOLLOWING THE MIDSUMMER PAUSE

After a midsummer pause of 1-4 weeks (usually 1 week) all species showed small increments of renewed elongation activity varying from zero up to 13 mm in any one week and totalling from 2 to 74 mm for the entire post-midsummer season. This range was 2-24 mm in *P. strobus*; 16-40 mm in *P. resinosa*; 6-41 mm in *P. sylvestris*; and 10-74 mm in *P. banksiana.* In 21 individuals out of the 200 measured the total elongation occurring after the midsummer pause was appreciably greater in amount than the original length of the winter buds at the beginning of the observations. It is reasonably certain that except for these 21 individuals the post-midsummer elongation observed is due to new bud elongation. Of the 21 individuals one was *P. strobus* and attained a post-midsummer elongation of 14 mm in excess of the length of the terminal bud at the beginning of the season; 3 were *P. resinosa* attaining an excess of elongation over original length of bud of 12, 10 and 10 mm respectively; 1 was *P. sylvestris* and attained an excess of elongation of 21 mm; and 16 were *P. banksiana* in which the elongation excess ranged from 10-49 mm. It is reasonably certain that these 21 cases represent real stem elongation after midsummer pause.

Two instances not included in the above were observed where the terminal bud awakened and gave rise to a short additional "internode" of growth. These were both in *P. strobus* and each one added an additional 33 mm of primary growth to that formed before the pause. The curve for *P. resinosa* in Kienholz's (4) paper apparently shows this post-midsummer-pause elongation but Cook's (2) data do not show it. This is no doubt due to his method of measurement. His measurements were taken weekly using a wooden yardstick and were read to the nearest one-quarter inch from a starting point marked with paint or wax crayon. The individual weekly increments following the midsummer pause were almost always too small to be detected by measurements of this type.

Table VII gives a picture of the time during which this extra elongation occurred. From the table it will be noted that 18% of the individuals of *P. strobus* continued the extra growth until and including the week ending September 11, 36% stopped after the following week and 8% showed some elongation between October 16 and December 4. The majority of the individuals of *P. resinosa* showed no further elongation after October 9, but 20% still showed elongation between October 16 and December 4. In *P. sylvestris* elongation entirely ceased in the majority of the individuals by October 2; and in *P. banksiana* the majority ceased by October 9. These dates appear late but they must be taken along with the fact that the rainfall for October was 232.40% (table I) of the normal-expected while the temperature continued unusually mild well into December.

TOTAL SEASONAL ELONGATION

In table VI the individuals are divided into height-classes and the average seasonal increment for individuals of each class is given. In all four species it will be noted that there is a definite relation between total increment and height of the individuals at the beginning of the season. Thus in *P. strobus* each succeeding taller class grew more than the class below it. The average ranged from 132 mm for the height-class below 50 cm to 518 mm per individual for the height-class above 300 cm. In *P. resinosa* the average elongation per individual was 339 mm for individuals initially 100 cm or less high, 432 mm for individuals in the 101-150 cm height-class, and 505 mm for those in the 151-178 cm height-class. The average total seasonal increment for *P. resinosa* reported by Cook (2) ranged from approximately 275 mm to 513 mm. In *P. sylvestris* the data show increasing average elongation with increase in height-class up to the 201-250-cm class but decreased elongation in one individual above that class. Average total increment varies from 303 to 787 mm. In *P. banksiana* the average increment per individual is 567 mm for 18 individuals of 100 cm or less initial height and 606 mm for 32 individuals initially between 101 and 139 cm high. It will be noted that *P. banksiana* shows the greatest average increment in relation to initial height with *P. sylvestris* second and *P. resinosa* third.

The present data do not deal with the question of relation between total growth and rainfall. There is no certain effect of rainfall upon the periodicity of growth or the type of curve exhibited.

DISCUSSION

From the practical standpoint of forestry the differences in the various types of curves exhibited by these pines is of little significance since they bear little or no relation to total amount of elongation for the season. It is true that the average elongation per individual is higher in *P. sylvestris* and *P. banksiana* (table VII) where curves of type I (table III) predominate but this difference is more likely a species difference rather than an elongation-type difference. On the other hand, from the standpoint of theoretical internal physiology, they are of considerable significance. All of the curves illustrate a grand-period type of behavior which results in a periodicity of elongation, the essential character of which is not obviously affected by external factors. The time when the elongation begins, the height of its peak, and the total amount of elongation are undoubtedly affected by external factors of the present season and indirectly, through amount of food reserves, by external factors of the past season. The effect of the total amount of elongation in one season upon that of the following season and their relation to external factors of the environment will be presented in a subsequent paper.

A discussion of the internal factors responsible for the grand-period type of growth behavior would be out of place here but it should be pointed out clearly that every type of curve exhibited by these pines except types A, B, and C present a modification of the simple grand-period behavior wherein a life process begins slowly, accelerates with increased tempo to a maximum then decelerates in somewhat the same, except inverse, order to a dragging minimum followed by complete cessation. When a modification of the simple grand-period type of behavior occurs on the left or accelerating side of the curve (curve-types E and H) the internal factors are more likely to involve modification of enzyme action in rendering food reserves available, assimilation reactions and water conduction problems than a matter of dwindling amount of food reserves. When a curve shows a flat top (curve D, table III, fig. 1), it is possible that the maximum amount of enzymes has been reached while the food reserves are still high and elongation rate is conditioned by rate of enzyme activity in rendering reserves available for assimilation and respiration. When the modification in the curve occurs on the right or decelerating side (curve types F and I), amount of enzymes can hardly be a factor since the total amounts are already greater than necessary, in view of the fact that they are not used up in the chemical reactions they promote. Such modifications are more likely related to dwindling supply of reserves. That they are due almost entirely to internal factors seems to be further indicated by the fact that, even though available water supply was greatly increased by excessive rainfall in early June this had no effect in modifying an already rapidly-declining elongation rate. The midsummer zero period was reached (table V) by the majority of individuals of all species at the very time when available soil water was at its highest for the season.

SUMMARY

1. Elongation was measured in 50 individuals each of *Pinus strobus, P. resinosa, P. sylvestris* and *P. banksiana* weekly from March 31 to October 16 with a final reading on December 4.

2. Elongation began for the majority of the individuals of the last three named species during the week ending April 13 and for the majority of *P. strobus* during the following week.

3. All individuals show a grand-period type of elongation behavior with the curves falling into 9 different curve-types.

4. The maximum in elongation rate was reached by all of the individuals of *P. banksiana* and the majority of those of *P. sylvestris*

during the week ending May 4 which was 4 weeks after initiation. In *P. resinosa*, the time thus elapsed was 6-7 weeks and in *P. strobus* it showed a spread of 4-7 weeks.

5. Abundant rains coming in June when all individuals were rapidly decelerating in elongation had no measureable effect in stopping the declining rate.

6. A midsummer zero-point in elongation rate is reached by all individuals. It is reached during the week ending June 16 by more individuals than during any other one week and by the majority of individuals of all species during the 2-week period ending June 23.

7. All species show a period of post-midsummer activity after a midsummer-zero point has been reached. In most of the individuals this extra elongation is due to bud activity but in some it is undoubtedly true axial elongation.

8. Total average seasonal increment per individual increases with increased initial height. This increment is 132-518 mm in *P. strobus*; 339-505 mm in *P. resinosa*; 303-787 mm in *P. sylvestris*; and 567-606 mm in *P. banksiana*.

ACKNOWLEDGMENT

The writer wishes to take this opportunity to express his sincere thanks for the courtesies shown by Mr. Charles Youngman in permitting study of all the individuals of *P. banksiana* and 17 specimens of *P. sylvestris* from the planting on his estate.

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TABLE I

Rainfall for the year 1941 as determined by the U. S. Weather Bureau at Columbus 17 miles from the site under observation.

Month	Rainfall	Normal-Expected	% of Normal
January	1.25 in.	3.69 in.	33.87
February	0.95	2.45	38.77
March	0.47	3.97	11.84
April	2.02	3.72	54.30
May	1.68	3.49	48.25
June	6.58	3.63	181.23
July	0.48	2.87	16.72
August	3.45	3.72	92.74
September	3.20	3.71	86.25
October	7.46	3.21	232.40
November	2.35	2.78	84.53
December	2.91	3.22	90.37
Total	32.80	40.66	81.07
Jan.-May	6.37	17.32	35.94
Aug.-Oct.	14.11	10.64	132.62

TABLE II

Initiation of vertical growth. Percentage of trees beginning growth during weeks shown.

Week Ending	*P. strobus*	*P. resinosa*	*P. sylvestris*	*P. banksiana*
April 13	30%	96%	82%	100%
April 20	66	4	16	0
April 27	4	0	2	0

TABLE III

Distribution of curve types among the species studied. Figures indicate the number of individuals of each species exhibiting each type of curve.

Curve types	*P. strobus*	*P. resinosa*	*P. sylvestris*	*P. banksiana*
A. Slopes of curve about uniform	0	6	3	1
B. Slope steeper on left	3	0	7	9
C. Slope steeper on right	15	22	3	0
D. Flat top—mostly steeper on right	12	10	1	0
E. Plateau on left	4	2	3	0
F. Plateau on right	3	1	1	2
G. Double peak—about equal	1	1	1	0
H. Double peak—lower on left	6	6	4	0
I. Double peak—lower on right	6	2	27	38

TABLE IV

Time of peak in rate of elongation. Percentage of trees showing peak each week.

Week Ending	*P. strobus*	*P. resinosa*	*P. sylvestris*	*P. banksiana*
May 4	6%	0%	74%	100%
May 11	18	2	6	0
May 19	14	28	0	0
May 26	38	60	18	0
June 2	24	10	2	0

TABLE V

Time of midsummer zero period. Percentage of trees reaching zero period each week.

Week Ending	*P. strobus*	*P. resinosa*	*P. sylvestris*	*P. banksiana*
June 2	0%	0%	2%	2%
June 9	4	2	14	16
June 16	44	66	54	44
June 23	32	8	18	20
June 30	12	8	6	16
July 10	4	6	4	2
July 17	4	10	2	0

TABLE VI

Showing relation of height classes to time of initiation of growth, time elapsed between initiation of growth and midsummer pause, and total seasonal growth.

Height Classes	No. of Individuals in each class	No. of individuals beginning growth during week ending			Weeks elapsed between initiation of growth and midsummer pause						Average total Growth for season
		4-13	4-20	4-27	7	8	9	10	11	12	
					Pinus strobus						
19-50 cm	6	3	3		2	3	1				132 mm
51-100	6	3	3			3	2	1			213
101-150	11	2	9		1	2	5			3	313
151-200	21	9	11	1		7	4	7	1	2	347
201-250	5	2	2	1		1	1	3			367
301-312	1		1					1			518
					Pinus resinosa						
56-100	12	11	1			2	8	2			339
101-150	27	26	1			1	22	4			432
151-178	11	11				1	8	2			505

TABLE VI—(Continued)

Height Classes	No. of Individuals in each class	No. of individuals beginning growth during week ending			Weeks elapsed between initiation of growth and midsummer pause						Average total Growth for season
		4-13	4-20	4-27	7	8	9	10	11	12	
					Pinus sylvestris						
77-100	4	2	1	1		2	2				303
101-150	21	17	4			7	13			1	524
151-200	22	18	4			3	11	7	1		605
201-250	2	2						1	1		787
251-294	1	1				1					589
					Pinus banksiana						
71-100	18	18				3	9	4	2		567
101-139	32	32			1	5	17	7		2	606

TABLE VII

Time of cessation of elongation. Percentage of trees showing no elongation after the weeks shown below.

Week Ending		*P. strobus*	*P. resinosa*	*P. sylvestris*	*P. banksiana*
July	17	4%			
August	7			2%	
	14	2		2	
	21	2		4	
	28	2		4	
Sept.	4		2%	8	4%
	11	18	10	12	6
	18	36	14	14	10
	25	14	14	28	14
Oct.	2	6	20	10	24
	9	4	14	8	24
	16	4	6	4	8
Elongation after 10-16		8	20	4	10

DENDROMETER STUDIES OF FIVE SPECIES OF BROADLEAF TREES IN INDIANA

By Ray C. Friesner

In a previous paper (2) results of a dendrometer and dendrograph study on *Fagus grandifolia* were given. The present paper presents results of an additional year of observations on the same species and a season of observations on four other species, viz. *Ulmus americana, U. fulva, Acer saccharum* and *Quercus alba.*

Observations on *Fagus grandifolia* extend throughout the calendar year 1941, those on *Ulmus fulva* began on April 14, and those on the other species began on March 3. In all cases observations included in the present discussion ended on December 22, 1941.

FAGUS GRANDIFOLIA

Previous studies on this species have been made by Dr. A. W. Gericke (5) and by the present writer (2). The former study was made during the season of 1919 on a tree near the Laboratory for Plant Physiology of Johns Hopkins University, Baltimore, Maryland, and the latter on three trees on the estate of Charles Lynn just north of Indianapolis.

In both studies growth changes were first noted coincident with the time of full expansion of the leaves, which in both instances was the middle of May. In the Baltimore tree growth continued until June 5 and showed intermittent growth, correlated with rains, until the latter part of September. In the Indianapolis trees diametral increase reached its maximum rate by the middle of June and continued with decreasing rate until the middle of July. From the last date until the end of the calendar year, decreases and increases alternated in correlation with rainless and rainy periods. At the close of the calendar year, one tree showed a net increase of 0.10 mm and the other a net increase of 0.082 mm over the radius at the time of cessation of increase in mid-July, thus indicating some growth activity subsequent to the time of ending of the main growth period.

Observations for the calendar year 1941 were limited to one tree (tree A of the 1940 period) which was 37.7 cm DBH. The diameter recorded by the dendrometer on December 30, 1940 was considered to be the zero point for the 1941 data. The period from this time until the end of the first week in May, 1941 was occupied by alternate increases and decreases (table I). The first changes which can be interpreted as growth changes occurred during the week ending May 12. This is one week after the time of full expansion of the leaves and three weeks after the flowers were fully developed. Thus, while leaves reached full expansion two weeks earlier in 1941 than in 1940 the time of beginning of growth activity was but one week earlier. During both seasons, growth continued with increased intensity, the peak in rate being reached in 1940 during the week ending June 17 and in 1941 during the week ending June 2. Growth reached a zero point in 1940 during the week ending July 15 and in 1941 during the week ending June 16. The abrupt ending of radial changes in 1941 is correlated with drought conditions. Table II shows very definitely that the 1941 growing season began with a decided rainfall deficit which continued until after the June pause had set in. This probably accounts for the shorter period of radial increase during 1941 as compared to 1940. The period from beginning of radial increase to its primary cessation was 9 weeks in 1940 and 5 weeks in 1941. The 1940 growth period was entered following unusual rainfall in both April and May (167.13% and 110.54% of normal, respectively), whereas the 1941 growth period was entered following 6 months of subnormal rainfall (January through May being 56.94, 24.17, 28.49, 52.76 and 28.79% of normal, respectively; table II). Behavior after the June pause was one of almost continuous loss until late August and early September in spite of the fact that 193.92% of normal rainfall came in June. Apparently this was too late to halt the decreases already initiated before it came. The maximum length of the radius for the entire year was reached during the week ending September 2. This was a total increase of 0.78 mm over the radius at the beginning of the observation period on December 30, 1940. Behavior subsequent to the September maximum consisted of alternate decreases and increases, the radius showing a net loss of 0.06 mm on December 22 as compared to September 2. The total radial increase of this tree was 1.02 mm in 1940 and 0.78 mm in 1941 in spite of the fact that total rainfall for the year November to October was 63.13% of normal in 1940 and 78.25% of normal in 1941. It is thus apparent that total rainfall is not nearly so important in this regard as the time and manner in which it falls.

A dendrometer was attached to one tree measuring 35.3 cm in diameter on March 3, 1941. Flower buds began to swell during the week ending March 31 (table III). Flowers reached full size during the week ending April 7 and fruits were full size 2 weeks later, i. e. during the week ending April 21. Radial increase began during this same week though vegetative buds showed no appreciable activity until one week later, i. e. radial increase began during the week ending April 21 while vegetative buds began to swell during the week ending April 28. Maximum size of leaves was reached 3 weeks (week ending May 5) after initiation of radial increase and 2 weeks after vegetative buds began to swell. Radial increase continued at varying rates (table I) until the end of July after which losses and gains alternated but with a further net increase of 0.16 mm by the end of the first week in September.

In the work carried on by Dr. F. T. McLean (5) the observations began too late to show the correlation between initiation of radial increase and bud, fruit, and leaf activity above mentioned. In the present observations maximal rate of radial increase occurred during the week ending June 2 and a further and still higher peak in rate occurred during the week ending June 30. In the former observations (by McLean) the maximum rate apparently came at about the same time as the first maximum in the present observations but cessation of growth came 3 weeks later in the present work than in that of McLean.

The observations by Lodewick (3, 5) show that radial increase reaches a high rate of activity, spring wood formation has ceased and summer wood formation begun by the time the leaves reach full size; and cambial activity is about at an end by August 1. In the present paper radial increase came to a pause by the end of July but an increase during the week ending September 8 carried the total length of the radius 0.16 mm greater than it was at the time when growth came to the July-end pause.

Dendrographic data did not begin until June during the first 2 weeks of which the curve shows a steadily upward trend. Reversible variations were recorded for each day of this period but their magnitude was greatly reduced by the fact that this was the only period for the entire growing season when rainfall exceeded 53% of the normal-expected (table II), by the fact that evaporation rate was below that for the periods before and after these 2 weeks (table 1), and by the further fact that the hours of sunshine were much below normal, with rain falling on 9 of the 14 days. The maximum magnitude of these daily variations was 0.11 mm between peak and trough of the curves, the peak occurring between 6 and 8 in the morning and the trough between 5 and 6 in the afternoon. Subsequent weeks showed similar reversible variations differing only in degree until the first week in October after which the curves showed essentially straight lines. The curve for the week ending August 4, however, merits special mention. On July 29 the curve began dropping at 8 a. m. falling gradually for a loss of 0.15 mm until 2 p. m. when a further drop of 0.23 mm occurred so suddenly as to show a vertical line on the chart. A slight further loss between 2 p. m. and 6 p. m. brought the total loss for the day to 0.40 mm. During the night there was a recovery of 0.18 mm but the following day showed a further loss of 0.30 mm with 0.15 mm recovery the following night. Again, on August 2, the curve showed a gradual decline from 9 a. m. to 3 p. m. with 0.18 mm loss followed by a vertical drop shortly after 3 p. m. of 0.65 mm, making a total drop for the day of 0.83 mm. A recovery of 0.20 mm occurred during the night. There was thus a net loss of 1.00 mm shown by the dendrograph for this week. Dendrometers showed the following correlations for the same week: Fagus, 0.05 mm loss; *Ulmus americana,* 0.16 mm loss; *U. fulva,* 0.08 mm gain; *Acer saccharum,* 0.30 mm loss; and *Quercus alba,* 0.46 mm loss.

ULMUS FULVA

A dendrometer was attached to a tree 27.5 cm DBH. April 14, 1941 at which time the tree was in full flower. Radial increase apparently was just about to begin for an increase of 0.02 mm was recorded for the week ending April 21. Initiation of radial increase came one week before the fruits had reached full size though only a total of 0.06 mm had accumulated by this time. By comparison, *U. fulva* was one week later than *U. americana* in time of flower and fruit activity (table III) and, though the former began growth at the same time as the latter, its first 2 weeks of growth were much slower than the latter (table I). By the third week the two species were essentially equal in total growth increment and from that time on *U. fulva* was never surpassed in growth rate by *U. americana.* Peak in growth rate occurred during the week ending June 16 and gradually fell to zero during the week ending September 2; growth thus covered a period of 19 weeks, 9 of which were occupied in rising to the peak and 10 in falling from the peak to the zero point. The period following the end of August was occupied by alternate losses and recoveries with the radius being 0.12 mm shorter on December 22 than on September 2. A maximum radial increase of 3.88 mm was recorded for the season. No previous published data on this species, secured by these methods, are known to the writer.

ACER SACCHARUM

A dendrometer was attached to a tree 22.5 cm DBH. March 3, 1941. Buds began to swell during the week ending April 14, flowers were fully developed one week later, and many leaves reached full expansion during the week ending May 5 (table III). Radial increase began during the week ending May 12 or one week after leaves had reached full expansion. In this regard Fagus and Acer were similar. These results are similar to those obtained by Dr. A. B. Stout on a tree in the New York Botanical Gardens as reported by MacDougal (5) in which radial increase was found to begin about the time when the earlier leaves reached full expansion. Rate of radial increase rose steadily for 4 weeks, dropped considerably for one week, and then rose again for 3 additional weeks to the highest peak in rate for the season during the week ending June 30 (table I). The rate then steadily declined until the end of July after which losses and recoveries alternated but with the final reading for the week ending December 22 showing a net loss of 0.84 mm as compared to the measurements at the time of cessation of growth.

QUERCUS ALBA

A dendrometer was attached to a tree measuring 21.9 cm DBH. on March 3, 1941. Buds began to swell during the week ending April 21 and leaves reached approximately full size during the week ending May 5 (table III). Radial expansion began during the week ending April 21, i. e. coincident with swelling of vegetative buds. In this regard *Quercus alba* was more like the two species of Ulmus than either Fagus or Acer. These results are similar in regard to correlation between bud activity and inception of radial activity to those found by MacDougal (5) in *Quercus kelloggii* and by Lodewick (3) in *Q. velutina* and *Q. borealis* var. *maxima.*

Following inception of radial increase further increases of varying weekly amounts are shown (table I) continuously until cessation of growth during the week ending August 4. The peak in growth rate occurred during the week ending June 30. A total of 1.96 mm of radial increase was recorded before cessation.

DISCUSSION

From the foregoing it appears that the ring-porous trees in this study (Ulmus and Quercus) show a much earlier inception of growth in relation to vegetative bud activity than the diffuse-porous trees (Fagus and Acer.). The former show inception of cambial activity essentially coinciding with awakening of vegetative bud activity and the latter have cambial activity delayed until time when leaves have reached full size or nearly so.

From tables I and III it will be noted that Fagus shows a much shorter growing period than any of the others included in this study. Judging from the much shorter growth period shown by Fagus in 1941 than in 1940 and noting from table II that the 1941 season was less favorable than 1940 from the standpoint of rainfall during the time of growth it seems clear that this species shows a greater sensitivity to reduced soil moisture than the other species. Not until June did anywhere near normal amounts of rain fall and this did not come in time to stave off a shortening of the growth period for this species. Acer and both species of Ulmus showed effects of the rainfall-deficit by a falling-off of the growth rate in early June and a late June pick-up following the heavy June rainfall. Of course, it is obvious that other factors are involved in determining growth rate but some of these, such as evaporation rate, are apt to be high when rainfall is low thus creating a greater demand for water at the very time when it is least available. On the other hand, the number of hours of sunshine is likely to be greater when rainfall is less and this would permit more carbohydrates to be made for construction of cell materials, but, again, water is necessary to produce the turgidity upon which real expansion would depend.

The role of hormones in growth activity of trees is not well understood but as pointed out by MacDougal (4, 5) the cambium is aroused from its resting condition only by hormones generated in the buds or stem tips. In most cases initiation of cambial activity shows a definite relation to bud activity. In the present study, the ring-porous species show initiation of cambial activity essentially coincident with awakening of vegetative buds while the diffuse-porous species showed initiation of cambial activity about the time of full expansion of leaves. It is probable that in the latter species compounds produced only by the leaves, and after they are fully expanded or nearly so, are necessary for awakening of cambial activity.

These studies do not fully agree with MacDougal's statement (4, p. 237) that "once awakened, cambium illustrates a fundamental capacity to operate unceasingly without pause or rhythm and at a rate modified only by external conditions and food-supply." In Fagus, Acer, and both species of Ulmus the growth curves show definite acceleration in rate until a peak is reached and a corresponding deceleration until growth ceases. In the present study Acer and Ulmus show double peaks but in all four species a definite rhythm or grand-period type of curve is shown. External conditions without doubt, play important roles in determining the time of initiation, time of peak rate and time of cessation of growth and the amount of growth, but the growth rhythm occurs independently of definable rhythms in the external environment. They are most likely due to internal physiological conditions, such as available hormones, amount of diversion of hormones and other growth substances to other activities. The writer has shown (5) that daily rhythms in rate of root elongation are due to internal causes, such as alternation of times of maximum cell division and cell elongation.

SUMMARY

1. Radial and diametral changes have been studied with dendrometers and dendrograph on *Fagus grandifolia* (second season), *Ulmus americana, U. fulva, Acer saccharum* and *Quercus alba.*

2. Growth changes in Fagus and Acer were first noted near the time of full expansion of the leaves and in Ulmus and Quercus near the time of awakening of activity of vegetative buds. In the case of Ulmus this was near the time of full size of fruits.

3. Rate of expansion in Quercus showed a more irregular curve than in any of the other species. All others showed a curve approaching the grand-period type.

4. Fagus had a much shorter growing period than any of the other species. The period was: Fagus, 9 weeks in 1940 and 5 weeks in 1941; *U. americana,* 15 weeks; *U. fulva,* 19 weeks; Acer, 12 weeks; and Quercus, 15 weeks.

5. Fagus appears to show a greater sensitivity to soil moisture deficit than the other species studied.

6. Daily reversible variations occurred in *Ulmus americana* (the only species studied with the dendrograph during this season) showing the greatest diameter in the early forenoon and the shortest diameter in the late afternoon.

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TABLE I

Weekly changes in radii of five species of trees together with meterological data.

Week ending	Radius changes										Meterological data		
	Fagus		U. americana		U. fulva		Acer		Quercus		Av. Mean Daily Temp.	Rainfall Inches	Av. Daily Evapor. Inches
	Current	Total	Current	Total	Current	Total	Current	Total	Current	Total			
1-6-41	–0.44	–0.44									-1.62°C	0.30	
1-13-41	0.34	–0.10									0.06	0	
1-20-41	–0.12	–0.22									0	0.76	
1-27-41	0.14	–0.08									0.29	0.62	
2-3-41	0.02	– .06									0.29	0	
2-10-41	–0.10	–0.16									–2.40	0.12	
2-17-41	0.12	–0.04									2.22	0.47	
2-24-41	–0.14	–0.18									–6.77	0	
3-3-41	0.14	–0.04									–0.40	0.19	
3-10-41	0	–0.04	0	0			0	0	0	0	1.18	0.30	
3-17-41	–0.20	–0.24	–0.10	–0.10			–0.20	–0.20	–0.36	–0.36	–0.40	0.12	
3-24-41	0.20	–0.04	0.28	0.18			0.16	–0.04	0.36	0	3.78	0.11	
3-31-41	0	–0.04	–0.02	0.16			0	–0.04	–0.02	–0.02	4.84	0.47	
4-7-41	0	–0.04	–0.16	0.			–0.02	–0.06	–0.12	–0.14	9.48	0.60	0.095
4-14-41	–0.12	–0.16	–0.06	–0.06			0	–0.06	0.06	–0.12	17.81	0.01	0.152
4-21-41	0.03	–0.13	0.22	0.16	0.02	0.02	0.02	–0.04	0.18	0.06	18.47	1.30	0.189
4-28-41	–0.03	–0.16	0.04	0.20	0.04	0.06	0	–0.04	0.06	0.12	11.48	0	0.153
5-5-41	0	–0.16	0.10	0.30	0.28	0.34	0.04	0	0.12	0.24	20.03	0	0.196
5-12-41	0.13	–0.03	0.02	0.32	0.12	0.46	0.20	0.20	0.06	0.30	13.37	0.68	0.126
5-19-41	0.08	0.05	0.16	0.48	0.04	0.50	0.32	0.52	0.06	0.36	17.25	0.21	0.175
5-26-41	0.15	0.20	0.08	0.56	0.12	0.62	0.40	0.92	0.04	0.40	22.25	0.02	0.295
6-2-41	0.22	0.42	0.38	0.94	0.42	1.04	0.46	1.38	0.20	0.60	25.98	3.26	0.275

TABLE I—(Continued)

Week ending	Radius changes										Meterological data		
	Fagus		U. americana		U. fulva		Acer		Quercus		Av. Mean Daily Temp.	Rainfall Inches	Av. Daily Evapor. Inches
	Current	Total	Current	Total	Current	Total	Current	Total	Current	Total			
6-9-41	0.14	0.56	0.06	1.00	0.42	1.46	0.12	1.50	0.23	0.83	22.75	1.34	0.200
6-16-41	0	0.56	0.16	1.16	0.44	1.90	0.22	1.72	0.21	1.04	19.25	2.26	0.117
6-23-41	0	0.56	0.08	1.24	0.28	2.18	0.42	2.14	0.16	1.20	25.13	0.28	0.202
6-30-41	0	0.56	0.46	1.70	0.40	2.58	0.56	2.70	0.42	1.62	27.63	0.10	0.241
7-7-41	–0.04	0.52	0.10	1.80	0.28	2.86	0.51	3.21	0.12	1.74	24.47	0.24	0.243
7-14-41	0.04	0.56	0.10	1.90	0.37	3.23	0.37	3.58	0.07	1.81	23.47	0.23	0.226
7-21-41	0.04	0.60	0.07	1.97	0.27	3.50	0.28	3.86	0.03	1.84	22.47	0.39	0.246
7-28-41	–0.10	0.50	0.21	2.18	0.20	3.70	0.16	4.02	0.12	1.96	29.24	0	0.261
8-4-41	–0.05	0.45	–0.16	2.02	0.08	3.78	–0.30	3.72	–0.46	1.50	28.46	0.35	0.324
8-11-41	–0.13	0.32	–0.04	1.98	0.04	3.82	–0.10	3.62	–0.06	1.44	27.75	0.06	0.266
8-18-41	0.27	0.59	0.06	2.04	0.04	3.86	–0.06	3.56	0.04	1.48	22.20	0.96	0.231
8-26-41	0.12	0.71	0.04	2.08	0.02	3.88	0.02	3.58	0.08	1.56	23.25	0.38	0.178
9-2-41	0.07	0.78	–0.04	2.04	0	3.88	0.02	3.60	0.04	1.60	24.42	0.84	0.211
9-8-41	–0.10	0.68	0.30	2.34	–0.06	3.82	–0.06	3.54	–0.10	1.50	24.69	0.51	0.138
9-15-41	–0.06	0.62	–0.12	2.22	–0.02	3.80	–0.08	3.46	–0.10	1.40	20.75	0.32	0.212
9-22-41	–0.10	0.52	–0.08	2.14	–0.06	3.74	–0.02	3.44	–0.08	1.32	21.64	0	0.198
9-29-41	–0.32	0.20	0.16	2.30	0.06	3.80	0.02	3.46	–0.24	1.08	18.87	0.18	0.161
10-6-41	0.42	0.62	0.08	2.38	0.06	3.86	–0.04	3.42	0.44	1.52	20.00	3.46	
10-13-41	0.02	0.64	–0.08	2.30	0	3.86	–0.16	3.26	–0.12	1.40	15.76	0.62	
10-20-41	0.03	0.67	0	2.30	0.02	3.88	0.02	3.28	0.04	1.44	16.31	1.17	
10-27-41	0.03	0.70	0	2.30	0	3.88	0.02	3.30	0.06	1.50	13.54	0.52	
11-3-41	0.01	0.71	0	2.30	0	3.88	–0.08	3.22	–0.06	1.44	9.70	1.53	
11-10-41	0.03	0.74	–0.04	2.26	0	3.88	0.04	3.26	0.06	1.50	4.51	1.10	
11-17-41	–0.02	0.72	–0.10	2.16	–0.02	3.86	–0.04	3.22	–0.08	1.42	8.59	0	

TABLE I—(Continued)

Week ending	Radius changes										Meterological data		
	Fagus		U. americana		U. fulva		Acer		Quercus		Av. Mean Daily Temp.	Rainfall Inches	Av. Daily Evapor. Inches
	Current	Total	Current	Total	Current	Total	Current	Total	Current	Total			
11-24-41	0.02	0.74	–0.02	2.14	–0.08	3.78	0	3.22	0.06	1.48	7.05	1.10	
12-1-41	0	0.74	0	2.14	0.04	3.82	0.02	3.24	–0.04	1.44	8.93	0	
12-8-41	0	0.74	0	2.14	–0.02	3.80	–0.02	3.22	0	1.44			
12-15-41	–0.10	0.64	0	2.14	–0.08	3.72	–0.04	3.18	0	1.44			
12-22-41	0.08	0.72	–0.04	2.10	0.04	3.76	0	3.18	0	1.44			

TABLE II

Rainfall in relation to normal. Seasons 1939-1941

Month		Rainfall	Normal-expected	Percentage of Normal
November	1939	1.15 inches	3.35 inches	34.32%
December	1939	1.13	2.98	37.92
January	1940	1.38	2.95	46.77
February	1940	2.38	2.73	87.18
March	1940	0.90	3.93	22.90
April	1940	6.05	3.62	167.13
May	1940	4.30	3.89	110.54
June	1940	1.88	3.62	51.93
July	1940	0.90	3.34	26.94
August	1940	2.91	3.31	87.91
September	1940	1.06	3.40	31.17
October	1940	1.15	2.78	41.36
Total	1939-40	25.19	39.90	63.13
November	1940	3.38	3.35	100.89
December	1940	2.58	2.98	86.57
January	1941	1.68	2.95	56.94
February	1941	0.66	2.73	24.17
March	1941	1.12	3.93	28.49
April	1941	1.91	3.62	52.76
May	1941	1.12	3.89	28.79
June	1941	7.03	3.62	193.92
July	1941	1.21	3.34	36.23
August	1941	1.40	3.31	42.30
September	1941	1.94	3.40	57.06
October	1941	7.19	2.78	258.64
Total	1940-41	31.22	39.90	78.25
May-Oct.	1940	12.20	20.34	59.98
May-Oct.	1941	19.89	20.34	97.79
May-Sept.	1941	12.70	17.56	72.32
Nov.-Apr.	1940	12.99	19.56	66.41
Nov.-Apr.	1941	11.33	19.56	57.92

TABLE III

Correlation of growth changes with other activities of the trees.

Activities	Fagus		Ulmus americana	Ulmus fulva	Acer	Quercus
	1940	1941				
DBH. at beginning of period —cm.	37.5	37.7	35.3	27.5	22.5	21.9
Flower buds begin to swell		4–21	3–31	4–7		none
In full flower		4–21	4–7	4–14	4–21	none
Vegetative buds begin to swell		4–21	4–28	4–28	4–14	4–21

TABLE III—(Continued)

Activities	Fagus		Ulmus americana	Ulmus fulva	Acer	Quercus
	1940	1941				
Fruits full size			4–21	4–28		none
Leaves full size	5–20	5–5	5–12	5–19	5–5	5–12
Radial enlargement begins	5–20	5–12	4–21	4–21	5–12	4–21
Radial enlargement reaches primary peak	6–17	6–2	6–2 6–30	6–16	6–30	6–30
Primary pause in radial enlargement	7–15	6–16	8–4	9–2	8–4	8–4
All radial growth-enlargement ceased	7–15	9–8	9–8	9–2	8–4	8–4
Increase during 1941—mm.	1.02	0.72	2.38	3.88	4.02	1.96
Interval between beginning and ending of growth—weeks	9	5	15	19	12	15

DISTRIBUTION OF INDIANA ORCHIDACEAE

By MARGARET ESTHER BRUNSON

Members of the monocotyledonous family, Orchidaceae, are found principally in the tropics and sub-tropics, but they are fairly well distributed all over the world except in desert and polar regions. This family contains the greatest number of species of any family in the vegetable kingdom: over 400 genera made up of nearly 15,000 species. In spite of their large number of species and wide distribution, they seldom are found in great quantities at any time.

From the standpoint of habitat there are two groups of orchids: epiphytic and terrestrial, but all those found in temperate zones, such as the United States, are terrestrials. From the standpoint of nutrition they again fall into two groups, viz. those with chlorophyll, and hence capable of making their own food, and those without chlorophyll. All but two of our genera belong to the chlorophyll-bearing group. Our terrestrial orchids are perennials of a high degree of specialization in structure particularly in the flowers. Some are large and showy while others are small and inconspicuous. There are some which are highly colored, while others almost lack color. They inhabit swamps, bogs, dry uplands, shady places, or open, sunny places.

This particular study includes 41 species belonging to 17 genera and deals with their general distribution over the United States and Canada and their local distribution in Indiana. No attempt has been made to deal with them in a taxonomic way involving species differentiation. The nomenclature is that of Deam's (1) "Flora" and in every case of change of name, his authority has been accepted. Distributions have been obtained from Deam's "Flora" and from the additions to the "Flora" published annually by a committee of the Indiana Academy of Science (3), though these publications have been supplemented by shorter works of various earlier authors dealing with local flora and distributions. Only those species which have been reported were studied and the fact that other species or new stations may be added later was not taken into consideration.

From the standpoint of distribution the species fall into 2 primary groups, viz. intraneous and extraneous, i. e. whether they are entirely within their range here or on the limits of it. As will be observed from table I the species intraneous to Indiana form the larger group.

TABLE I

Species of Orchidaceae present in Indiana with respect to intraneous or extraneous distribution and according to botanical areas within Indiana. L=Lakes; T=Tipton Till Plain; ID=Illinois Drift Plain; LWV=Lower Wabash Valley; C=Chestnut Oak Uplands including adjacent unglaciated area; I=Intraneous; E-N=Extraneous to north; E-S=Extraneous to south; and E-E=Extraneous to east.

Species	L	T	LWV	C	ID
Cypripedium reginae (I)	x	x			
C. candidum (I)	x				
C. parviflorum (I)	x	x			
C. p. var. pubescens (I)	x	x		x	?
C. acaule (E-N)	x				
Orchis spectabilis (I)	x	x	x	x	x
Habenaria flava (I)	x			x	
H. viridis var. bracteata (I)	x	x			
H. scutellata (E-S)			x		
H. dilatata (E-N)	x				
H. hyperborea (E-N)	x				
H. clavellata (I)	x			x	
H. orbiculata (E-N)	x	x			
H. hookeri (E-N)	x				
H. ciliaris (I)	x				
H. lacera (I)	x	x			
H. leucophaea (I)	x				
H. psycodes (I)	x	x			
H. peramoena (E-S)				x	x
Pogonia ophioglossoides (I)	x	x			
Triphora trianthophora (I)	x	x	x	x	x
Isotria verticillata (E-E)	x			x	x
Arethusa bulbosa (E-N)	x	x			
Epipactis latifolia (E-N)	x				
Spiranthes beckii (E-N)				x	x
S. gracilis (I)	x	x		x	x
S. lucida (E-N)	x	x			x
S. ovalis (E-S)				x	x
S. cernua (I)	x	x	x	x	x
Goodyera pubescens (I)	x	x		x	
Calopogon pulchellus (I)	x	x		x	
Corallorrhiza wisteriana (E-S)		x	x	x	x
C. maculata (I)	x	x		x	x
C. trifida (E-N)				x	
C. odontorhiza (I)	x	x		x	x
Malaxis unifolia (I)	x				x
Liparis liliifolia (I)	x	x	x	x	x
L. loesellii (I)	x	x			

TABLE I—(Continued)

Species	L	T	LWV	C	ID
Species	L	T	LWV	C	ID
Tipularia discolor (E-S)				x	x
Hexalectris spicata (E-S)				x	
Aplectrum hyemale (I)	x	x		x	x
Totals—41 species; 25 I; 16 E	33	22	6	21	16

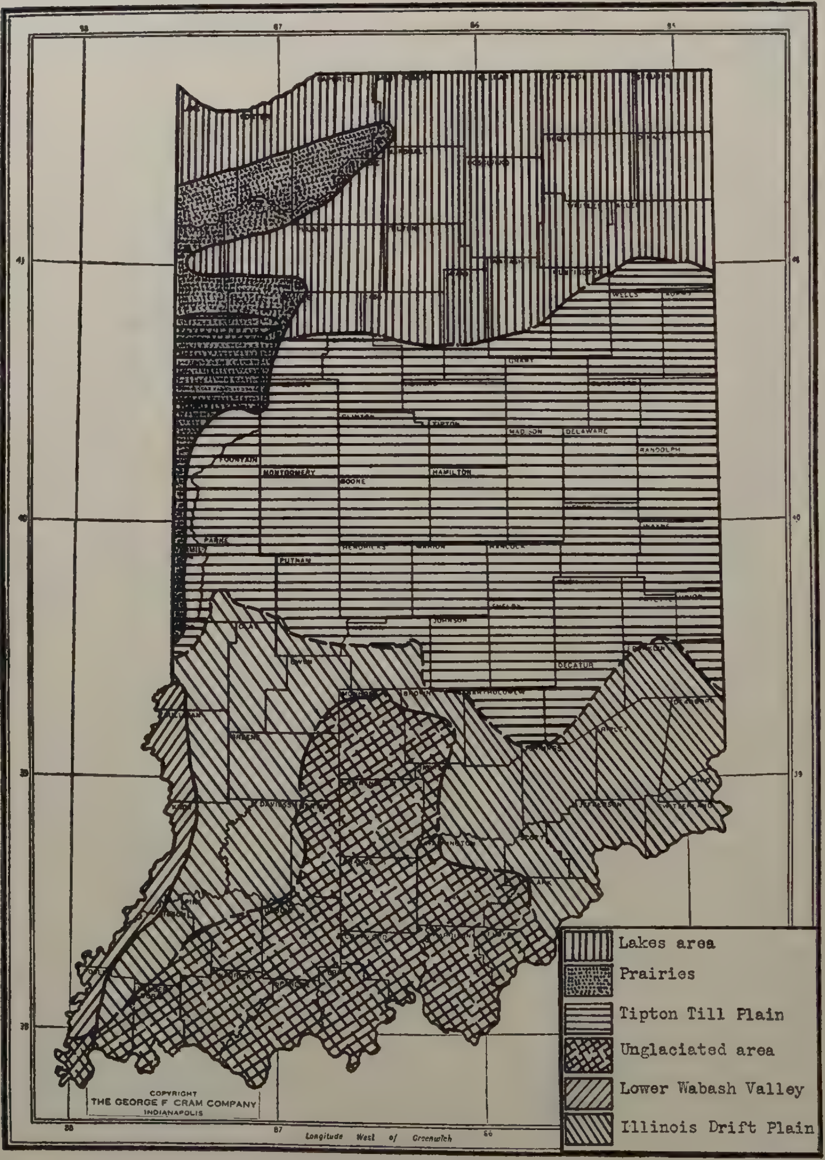
Of these 41 species of this family, 25 are intraneous in their range and 16 are on the borders of their range in Indiana. Of the 16 extraneous species, 5 are on the northern limits, 11 on the southern limits and one on the western limits of their range.

When the Indiana species are compared as to the botanical areas they occupy, the state may be divided as modified from Deam's (1) "Flora" into Lakes area, Prairies, Tipton Till Plain, Chestnut Oak Uplands including the unglaciated area, the Lower Wabash Valley and the Illinois Drift Plain, as shown in map 1. No orchids are found in the small Prairie area in the state, so this portion will not be considered.

As is seen in table I, four species are present in all of the botanical areas listed for Indiana (except the Prairies). These species are *Orchis spectabilis, Triphora trianthophora, Spiranthes cernua,* and *Liparis liliifolia.* They are all in the midst of their range here and the soil in all the areas will support their growth.

Some species are restricted to but one botanical area. Such species as *Cypripedium candidum, C. acaule, Habenaria dilatata, H. hyperborea, H. clavellata, H. hookeri, H. ciliaris, H. leucophaea,* and *Epipactis latifolia* inhabit only the Lakes area. The Lakes area has more members of this family represented than any other area in the state. There are 33 orchids to be found in Indiana's northern lakes region, because the boggy nature of the soil and the relatively less agricultural disturbance by man is a habitat most conducive to their growth. The Tipton Till Plain is next in frequency of Orchidaceae having 22 represented, and Chestnut Oak Upland follows closely with 21 represented. Illinois Drift Plain is next in frequency with 16, and the small region of Lower Wabash Valley trails with 6 species.

In connection with the intraneous species it is interesting to note that often the plants are nearing the edge of their range in Indiana, i. e. the bulk of their distribution is in one direction or another with Indiana close to one of the edges but not close enough to permit the distribution to be considered extraneous. For instance, a nothern orchid such as *Cypripedium parviflorum* will come into Indiana and Ohio and terminate its southern distribution in Kentucky and Tennessee; or a southern orchid as *Triphora trianthophora* will reach into



Indiana and Illinois but Wisconsin will be the limits of its northern distribution. There are other examples of species, the bulk of whose distribution is to the north or to the south of Indiana. *Orchis spectabilis, Habenaria viridis* var. *bracteata, H. leucophaea, H. psycodes, Corallorrhiza maculata*, and *Liparis loeselii* are examples.

Table II shows where Indiana orchids extend the bulk of their range. If the larger percentage of occurrence is in the south, then it is listed as a southern orchid, and so on. No representatives of truly western orchids are found to extend as far east as Indiana, but there are many eastern orchids which are prevalent in this state with the northern and northeastern members coming next in prevalence.

TABLE II

Where Indiana Orchidaceae extend the bulk of their range

Distribution	Number of Species
Extraneous	
On the northern limits	5
On the southern limits	10
On the western limits	1
Total species	
Main distribution northward	10
" " southward	5
" " eastward	13
" " westward	0
" " northeastward	6
" " southeastward	3
In the middle of their range	4

The fact that 16 of the 41 species (26.87%) are extraneous bears out Friesner's (2) statement that a substantial percentage of plants in Indiana are on the limits of their range and are critically situated in the state with respect to their distribution.

SUMMARY

1. A study was made of the monocotyledonous family, Orchidaceae, as it is represented in Indiana and as those species are distributed in United States and Canada.

2. Of the 41 species in 17 genera, 25 are intraneous and 16 are extraneous with respect to their range in Indiana.

3. The extraneous orchids fall into groups according to their northern, southern or eastern extension of the range.

4. The intraneous species fall into groups being classified as southern, northern, eastern, northeastern, southeastern and middle according to where the bulk of their distribution lies.

ACKNOWLEDGMENT

The writer wishes to thank Dr. Ray C. Friesner for his suggestion of the problem for this paper, for his encouragement, and for critical reading of the manuscript.

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FOREST SUCCESSION IN THE TROUT LAKE, VILAS COUNTY, WISCONSIN AREA: A POLLEN STUDY[1]

By J. E. POTZGER, Butler University, Indianapolis, Indiana

RUTH REBEKAH RICHARDS, Milwaukee-Downer College,
Milwaukee, Wisconsin

The lake forest in Wisconsin, and at least in parts of Michigan, is characterized by a contrasted variation in the dominants controlling the crown cover in the stand: one consists of Pinus, in less favorable, sandy habitats, the other of species of the northern hardwoods (*Acer saccharum, Betula lutea, Tsuga canadensis,* and eastward also *Fagus grandifolia*), which occupy the better clay and loam soils. As pointed out in a previous study on the Gillen Nature Reserve (5), the hardwoods complex is the more recent invader in Vilas county and adjacent areas in Wisconsin and upper Michigan, perhaps even in the whole lake forest region as indicated by pollen profiles from New Jersey (8). Earlier pollen studies by Potzger and Wilson (9), Smith (11), and Moss (3) in Michigan and Indiana indicate that a simple Pinus dominance gave way to invasion by broadleaved genera, which in the lower latitudes consisted chiefly of Quercus. As pointed out for the Gillen Nature Reserve (5), the northern hardwoods (Tsuga, Betula, Acer [?]) replaced to a marked degree the long-time Pinus dominance which had superceded Picea, the first invader after glacial retreat. The present paper is another chapter in the study of vegetational history of the Vilas county, Wisconsin neighborhood, stressing this time the area immediately adjacent to Trout lake, which as a whole is controlled by Pinus, and revolved in a Pinus dominance to the present time. Two smaller tracts of forest primeval are still existing at or near the lake, viz., the Point Woods T. 41 N., R. 6 E., Sec. 9, and the 60-acre tract owned by the Dairymen's Country Club, T. 42 N., R. 6 E., Sec. 6 (center). The constitution of these forests is shown in tables 1 and 2. Large acreage between Trout lake and for miles in all directions from the lake are today devoid of all climax forest cover, the vegetation consisting primarily of the low shrubs *Comptonia peregrina* and species of Vaccinium, with scattered clumps of Amelanchier, scrubby specimens of *Quercus borealis* var. *maxima* and luxuriant cover of *Pteridium aquilinum* var. *latiusculum*. There is no indication of an invasion by hardwoods, but all seems to be marking time for the day when Pinus will have advanced from centers of seed trees to take possession of areas where it constituted the dominant tree layer for many thousands of years. Areas adjacent to seed trees readily yield to re-occupation by Pinus. An eighth-acre tabulation in a recently invaded tract adjoining the Dairymen's Country Club forest, which had been completely denuded of trees, shows 108 stems of young *Pinus strobus* and 4 of *Pinus resinosa*. The next adjoining one-eighth acre supported 82 stems of *Pinus strobus* and 16 of *Pinus resinosa*. Species of broadleaved trees were limited to depauperate stems of *Acer rubrum*. In view of these facts, one wondered what the records in peat would show for this region. The analysis of deposits from five bogs included in this paper answers the question at least in part.

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[1] Contribution 125 from the botanical laboratory of Butler University, Indianapolis, Indiana; and notes and reports 109 from the Limnological Laboratory of the Wisconsin Geological and Natural History Survey, University of Wisconsin.

TOPOGRAPHIC AND VEGETATIONAL FEATURES

Pleistocene deposits determine the surface geology of Vilas county. The topography is rolling with occasional stretches of level outwash plains. The high Winegar moraine is only about 12 miles north of Trout lake. The soil for the most part is sandy or gravelly, and so presents edaphic problems of inadequate water supply to plants. The landscape is pitted with numerous lakes and bogs. Now and then one encounters small patches of northern hardwoods, but as a whole it was and still is potentially a pine territory; and the absence of this crown cover is due to the complete destruction of older seed trees by lumbering and subsequent fires.

BOGS STUDIED

For lack of convenient specific names, four of these depressions have been designated by alphabetical terms.

Bog A (Forestry Bog Lake). This little bog is less than one-eighth of a mile north of the Wisconsin Limnological Laboratory, on the State Forest Headquarters property, T. 41 N., R. 6 E., Sec. 8 (ne. quarter). A small open pool occupies the center, but most of the mat is covered by a scrubby growth of *Larix laricina* and *Picea mariana*. In 1937 L. R. Wilson and E. F. Galloway (14) studied an incomplete core of approximately 15 foot depth in the same bog, but did not penetrate to the original lake bottom.

The boring for the present study was made about forty feet southeast of the pool, approximately in the center of the depression. With the assistance of Mr. V. E. McKelvey, geologist with the Wisconsin Geological and Natural History Survey, we were able to exert sufficient pressure on the borer to penetrate the layers of fine sand over-lying coarse sand. Sediments were mixed with fine reddish sand at the 24-foot level and became very sandy at the 27-foot level, which condition persisted to the 31.5-foot level. Boring at Bog A represents the deepest one made in Vilas county bogs.

Bog B. The small, deep-set kettle hole promised a deeper layer of organic matter than the 6.5 feet which we obtained. The depression is only about 200 feet across, the peat has solidified completely and is now covered by straggling growth of *Picea mariana.* It is 0.2 mile southwest of the intersection of highways M and N, on the east side of highway M (T. 40 N., R. 6 E., Sec. 30 [ne. quarter]).

Bog C. The area covered by this bog is approximately 1,000 by 2,000 feet. It is an ice-block type depression flanked by steep slopes which at some places reach an elevation of 50 to 75 feet above the mat. The bog is in a late stage of filling, with a pond approximately 100 to 150 feet across occupying the eastern section. A quaky mat, densely capped with Sphagnum, covers the major portion of the depression. *Picea mariana* and *Larix laricina* form a dense forest about the rim, and have even invaded the mat in straggling colonies. The first core was taken about 50 feet west of the pond and sand was struck at 17 feet. A second boring about 15 feet west of the open water yielded additional peat samples to a depth of 24 feet. The bog is located on the east side of highway M, 1.4 miles north of U. S. 51 (T. 40 N., R. 6 E., Sec. 31 [nw. quarter]).

Bog D (Cardinal Bog). The beautiful little bog on the property of the Cardinal Resort is located at T. 41 N., R. 6 E., Sec. 14. It is hidden even from the nearby U. S. 51 by a dense encircling forest made up of *Picea mariana, Larix laricina* and *Abies balsamea.* An open pond about 75 feet across occupies the center. The boring was made approximately 10 feet from the open water, along the northern edge of the pond. Total depth was 22 feet.

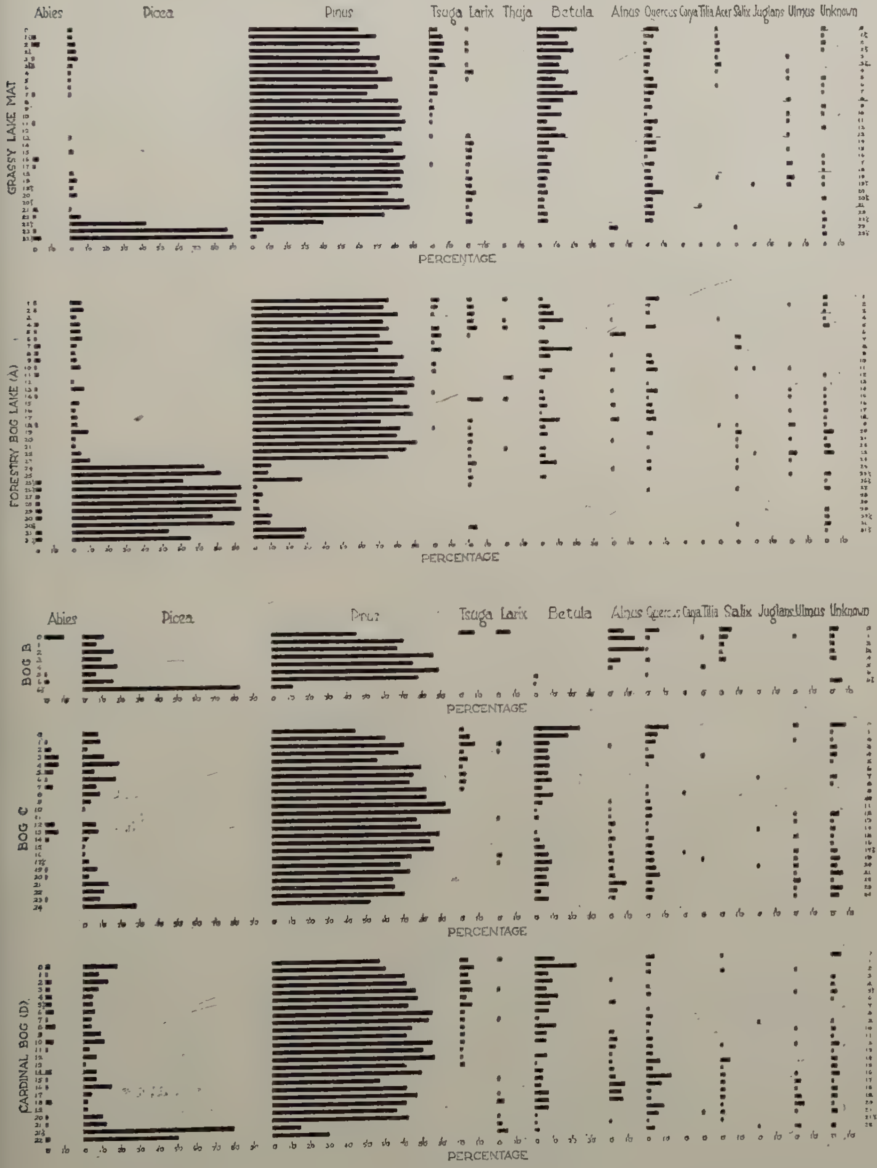
Grassy Lake Mat. The mat covering the southwest border of Grassy lake may be described in superlative terms with respect to quakiness. A luxuriant growth of Sphagnum forms the carpet layer while *Camadeaphne calyculata* and *Myrica gale* at times form dense thickets, yielding in some places to Larix. Boring was begun close to the open lake but moved progressively shoreward when eight feet yielded no sample. A complete core was finally secured approximately 100 feet southwest of the open water. The exact location is T. 42 N., R. 6 E., Sec. 4 [se. corner]).

METHODS

Samplings were taken with the movable sleeve, cylinder-type borer. A small portion of sediment was removed from the center of the inside cylinder and placed into a properly labelled bottle. In the laboratory, separation of the peat was accomplished according to the Geisler (2) method. Glycerine jelly was used as mounting medium. Since the forest complex in this part of Wisconsin is so simple, only 100 pollen grains were counted for each foot-level. Recordings kept in two 50-grain tabulations showed an almost identical percentage representation of the leading genera. An attempt was made to separate the pollen of *Pinus banksiana* from that of the other two pines, but the recommended diagnostic characteristics did not prove satisfactory in this study when check counts were made by several workers in our laboratory. Our experiences were similar to those reported by Deevey (1) in his work in Connecticut. For this reason we list Pinus only generically. Prompted by an inquiry from Dr. L. R. Wilson of Coe College on our method of separating Abies from Picea, and a subsequent detailed study of the pollen of these two genera, we came to the conclusion that the differentiation between the two on size of pollen, as given in Sears (10), which we had followed in previous work, is not tenable, certainly not with *Picea canadensis,* and led to the erroneous high percentages for Abies given in our previous publications. A check count was made in the present study on all earlier tabulations, and this places Picea into great prominence in the lower levels while Abies becomes of minor importance. No doubt the same change in importance of Abies in favor of Picea will be true for published records of Indiana lakes and bogs.

RESULTS

With some difference in degree and apparent duration of control, all bogs except C show an initial Picea dominance, with Pinus present from the beginning. We consider the condition as to degree and length of dominance of Picea in bog A as typical for the region, and that in the other depressions the lowest part of the profile is missing either because of borings omitting layers of sand with pollen, (see



levels 26 to 31.5 for bog A) or because the boring could not be made in the originally deepest part of the old lake basin. This latter type of defect is likely to be true for boring in bogs C and D, where a pond of considerable size still occupied the central area of the depression. A study in progress now indicates proof of such errors in borings and the incorrect conclusions drawn from such results.

The story of vegetational succession is short in the Trout lake area. Pinus succeeded Picea and held its dominance to the present day (tables 1 and 2). It differs from that of the Gillen Nature Reserve (5) which is about 15 miles north, in that the northern hardwoods have not yet invaded. Tsuga is represented by a very small percentage in all five pollen profiles (figs. 1 and 2), the Betula pollen present resembles mostly that of *Betula papyrifera,* and thus would be part of the Pinus dominance complex, playing an important role during periods of decline of a stand, or after catastrophic destruction of a forest. The most striking single feature of all five profiles is the long and complete dominance by Pinus.

Quercus could best be characterized as an early invader, and persisting as a non-aggressive constituent of the arboreal layer. Tables 1 and 2, likewise, reflect such a sociological status for this genus.

DISCUSSION

Northern Wisconsin and Michigan offer a splendid opportunity for pollen workers to obtain actual facts on the behavior of the two forest-cover types controlling larger or smaller areas in the lake forest region, and to ascertain whether the complex of conifers and broadleaved genera moved as an entity or whether the broadleaved element was a later intrusion into the uniform coniferous dominance, controlled by climate, and whether localized areas with least favorable soil conditions had experienced fluctuation in forest dominance. The study in the Gillen Nature Reserve (5) was concerned with the former question and this paper with the latter. The initiation of a cool-dry following a cool-moist climate of the Picea dominance apparently favored Pinus to the extent that it almost completely replaced Picea. No doubt because of greater height it reduced light on the forest floor and so interfered with the development of seedlings of the intolerant Picea. The striking "sudden" disappearance of Picea marks, perhaps, the decline of the then existing uniform stand and the culmination of compensating reproduction of the genus.

Increase of Picea towards the upper foot-levels of the bogs evidently indicates more solidified mats and invasion by *Picea mariana*

In the sandy Trout lake region, Pinus maintained dominance to the present day, but increased aggression of broadleaved genera made itself felt. This was pointed out by Wilson and Galloway (14). It is interpreted by us as marking the initiation of moderating climate at which the northern hardwoods invaded and assumed control in more favorable places. Tables 1 and 2 show that *Acer saccharum*, *Acer rubrum*, *Betula papyrifera* and *Quercus borealis* var. *maxima* have a fair representation in the small-size classes, but they maintain more a position of second layer trees in the dominant pine stands. In the newly invaded denuded areas east of the forest on the Dairymen's Club property, broadleaved species were wanting. To judge from the pollen profiles of the Gillen Nature Reserve (5) we must conclude that the climatic change which initiated Pinus dominance has more recently undergone further changes by way of moderated temperature and increased moisture, which favored an invasion by the broadleaved forest. This injects the problem of climatically controlled dominance for the region. Weaver and Clements (12) say, "The lake forest consists of a single association in which *Pinus strobus, P. resinosa* and *Tsuga canadensis* are the climax dominants." Nichols (4) takes a still broader view of the climatic climax when he calls it "a mesophytic forest comprising a mixture of evergreen coniferous and deciduous broadleaved trees," which involves all species, both needleleaved and broadleaved, alike. However, as soon as pine constitutes almost pure stands on sandy stretches he no longer considers them climatic climax, but calls them a "physiographic climax." This would perhaps best fit the "postclimax" of Weaver and Clements (12). Whitford (13) separates the two elements, considers broadleaved with Tsuga as co-dominant as climatic climax, and pine in the hardwoods association as "relics of a previous pine forest." Pollen profiles support this latter view. All profiles from southern Michigan, Minnesota, Wisconsin, some from Indiana and New Jersey (8) show a period of complete dominance by Pinus and a partial or entire replacement by broadleaved genera. From studies of pollen profiles of bogs in the various states mentioned above, as well as from observations during boyhood days in Presque Isle county, Michigan, the senior author has always been impressed with the fact that Tsuga is not a co-dominant with Pinus but rather characteristically forms a part of the later invading northern hardwoods crown cover (see figures 1 and 2, and tables 1 and 2). The results of pollen studies force to the conclusion that Pinus in the lake forest at present plays a role of postclimax, controlled by edaphic factors. In the southern extension of the range of this forest Pinus is today being replaced by Quercus, as a survey now in the making will show. This is but a repetition of the fate of Pinus from Indiana northward as shown with so monotonously uniform regularity in all pollen profiles. As Potzger and Friesner (6) pointed out, the boreal and the buffer lake forest with it, are moving northward, giving way to the climatically favored southern broadleaved element. In more rigorous sandy habitats, as about Trout lake, Pinus is still favored by edaphic factors, as the vast treeless areas easily yielding to Pinus invasion, when centers of germule dissemination are available, show. The status of the pine and northern hardwoods in Wisconsin and upper Michigan is similar to Quercus-Carya and mixed hardwoods in central Indiana, as discussed by Potzger and Friesner (7). There edaphic factors, primarily soil moisture, maintain a Quercus-Carya dominance in a climatically-favored mixed hardwoods region.

The rather elusive time element entering the discussion of any pollen profile is interesting, but always a factor modified and often distorted by the method of deposition itself as well as by imperfections in the sampling technique. Here enters especially the old question, has the core penetrated to the original ancient lake bottom? All the instruments used in bog boring work known to the authors fail to take samples at all in sandy layers, or only under various difficulties, at least when the sand is very coarse. In this respect the Wilson (15) sampler, used in lake borings, is the most satisfactory instrument to date, for it can take samples in sandy sediments. From bog studies in Wisconsin and lake sediments from Minnesota, Michigan and Indiana, the senior author has come to the conclusion that in sandy regions pollen of early invaders was deposited with fine sand long before much organic matter and eventually peaty deposits participated in the filling process. For that reason we feel that conclusions affixing time of duration to the Picea climax are, to say the least, of very doubtful value, unless layers of fine sand are included in the core. In the present study we feel that in all but bog A the length of time indicated by foot-level persistence of Picea is too short, due, very likely, to some errors in the sampling process. While the story of vegetational history is to all appearance complete in the shallow bog B, the time scale is much compressed, with the probability present that some parts of the time of deposition are wanting.

SUMMARY

1. The paper reports on a pollen study of five bogs in the region adjacent to Trout lake, Vilas county, Wisconsin.

2. Forest succession was uniformly in all bogs from Picea to Pinus, and Pinus held complete dominance to the time represented by the top-most level.

3. Decline of Picea and ascendency of Pinus was sudden. This is interpreted as interference with reproduction in Picea when Pinus replaced the old stand.

4. Diagnostic characters recommended by several workers for separating pollen of *Pinus banksiana* from other species of Pinus were found unsatisfactory when check counts were made of the same foot-levels by several workers in our laboratory and for that reason Pinus is listed again as a genus only.

5. When the region considered in this study is compared with that occupied by the Gillen Nature Reserve, 15 miles north of Trout lake, the former area lacks the more recent climatically favored northern hardwoods succession. The status of Pinus is described as one of postclimax, maintained by edaphic factors.

6. The difference in numbers of levels in the several bogs where Picea showed dominance was explained on basis of incomplete cores, either because of missing layers of sand which constituted much of early sediments, or inability to make borings in the deepest part of the old lake basin because of open ponds.

ACKNOWLEDGMENTS

Appreciation is expressed to the Wisconsin Geological and Natural History Survey for the opportunity given the senior author to serve on their staff during the summer of 1940; to the Wisconsin Alumni Research Foundation whose grant of funds supported the field work. Grateful recognition is also made of the assistance rendered by Messrs. V. E. McKelvey and Thomas H. Flanigon, members of the staff at the Limnological Station, for assistance given in the boring of bogs A and B.

To Miss Jane L. Goodlet, assistant in the Butler University Department of Botany, we are indebted for the lettering on the graphs.

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TABLE I

Composition of the Point woods at Trout lake based on 20 100-square-meter quadrats.

	Size-classes of stems							
Species	Below 1 inch	1-5	6-10	11-15	16-20	Above 20	Total	% F. I.
Abies balsamea	18	5	1				24	35
Acer rubrum	36	54	4				94	90
A. saccharum	62	95	4				161	60
A. spicatum	1						1	5
Alnus incana	1						1	5
Amelanchier sp?	18	15					33	60
Betula lutea		1					1	5
B. papyrifera		11	2				13	60
Corylus rostrata	374						374	90
Lonicera sp?	17						17	30
Picea canadensis		1					1	5
Pinus resinosa		5	4	42	28	9	88	100
P. strobus		43	4	4	2		53	60
Quercus borealis var. maxima	6	36					42	55
Thuja occidentalis		1					1	5

TABLE II

Composition of the pine woods on Dairymen's Country Club property based on 50 100-square-meter quadrats.

	Size-classes of stems							
Species	Below 1 inch	1-5	6-10	11-15	16-20	Above 20	Total	% F. I.
Abies balsamea	97	205	2				304	74
Acer rubrum	57	103	7				167	74
A. saccharum	10	71	11				92	60
Amelanchier sp?	2	3	1				5	10
Betula papyrifera	2	21	3		1		27	16
Corylus rostrata	101						101	44
Pinus resinosa	1	1	5	21	41	9	78	70
P. strobus	10	5	20	38	42	18	133	94
Prunus pennsylvanica		1					1	2
P. virginiana	4	14					18	16
Quercus borealis var. maxima	1	4	3				8	12
Tsuga canadensis			2				2	4

PHYTOSOCIOLOGY OF THE COX WOODS: A REMNANT OF FOREST PRIMEVAL IN ORANGE COUNTY, INDIANA

By J. E. POTZGER, RAY C. FRIESNER AND C. O. KELLER

When civilized man first set foot on the continent of North America, the whole eastern third of what is now the United States was covered by a magnificent broadleaved forest, known to the ecologist as the Eastern deciduous forest. It spread inland from the Atlantic coast to the great prairie, and arms of it as line-like extensions along river courses penetrated even the grasslands. Regions originally covered by the deciduous forest had been for ages the chief agricultural centers the world over, while the grasslands were until recently, with the advent of drilled wells and rail transportation, left to the nomad and herdsman. So it was but natural that the fate of the deciduous forest in Europe was also to become the fate of the broadleaved forest in the new world. The early settlers began with vigor to clear the land of its forest primeval, and considered forests a menace rather than a blessing, as the early volumes of the agricultural and natural history reports for Indiana clearly show. The sad part of it all is that so frequently poor judgment was used in selecting sites for potential farms; areas with high relief soon became submarginal as agricultural lands, and erosion swept away the shallow soil which forests had built up laboriously, and held for ages. The greater part of Indiana was originally well wooded, and its white oak became famous on all world markets, but the persistent lumbering and clearing activity during the past century reduced the once continuous cover of trees to open farmland or badly mutilated forests of young trees. Even the rugged Knobs area is today but in name a forest region. Our study (13) involving 5.5 miles of quadrat tabulations recorded only 129 stems above 20 inches DBH. Today Indiana forests are primarily in a stage of secondary succession, and small tracts, comparatively little disturbed by cultural influences, with tree giants which have absorbed for centuries the radiant energy of light, and stored it in their massive trunks, have become so rare that they arouse interest and curiosity of the public at large. Little wonder then that the Cox woods should become famous overnight, and the appeal to prevent the slaughter of trees which occupied their present site while our nation developed from insignificant colonies to a mighty world power was carried by the press to perhaps every larger city of our nation. The successful efforts of the organization set in motion to raise the funds necessary to purchase the Cox woods gave the potential huge saw logs of walnut, white oak, tulip poplar and beech another lease on life. They are to stand as monuments representative of the once massive eastern deciduous forest, to which generations of today and tomorrow might make their pilgrimage, to see in impressive miniature what pioneers of four score years tell us about the forest primeval which towered over the cabins of their boyhood days. The Cox woods has become a national forest, and it will carry the name of INDIANA PIONEER MOTHER'S MEMORIAL FOREST. Realizing that the feet of countless thousands of visitors will soon modify (in spite of all precautions which the Forestry Department will make) the natural laws under which forests reproduce and perpetuate themselves, a study of the sociology of the woody species in this bit of forest primeval was undertaken before paths will beckon to the nature lover and the merely curious. The field work was carried out on January 23 and 24, 1942.

LOCATION AND SIZE OF AREA

The Cox woods is located in Orange County, Indiana, 1.5 miles south of Paoli, on the east side of highway 37 (T. 1 N., R. 1 E., Sec. 7 and T. 1 N., R. 1 W., Sec. 12). The property comprises approximately 200 acres, of which 40 to 60 acres are comparatively little disturbed forest. For desirable comparison, the ecologist also finds various lesser stands in different stages of development, making possible enlightening comparisons between the beginning and culmination of the forest primeval.

GEOLOGY AND PHYSIOGRAPHY

Orange county occupies a central position in the Knobs area (more recently designated as the Chestnut Oak Upland) located in the south-central part of Indiana, which Deam (5) dscribes as the "hilliest part of the state." It involves the major part of the unglaciated section. Geologically it belongs to the famous Karst region of Indiana, named by Malott (9) the Mitchell Plain, characterized by short intermittent streams, sinkholes, caves and other sub-surface drainage phenomena. The noted Lost River is only five miles north of the woods. The characteristic surface features of the region as a whole also find expression in the area occupied by Cox woods. A number of sinkholes pit the surface, and introduce new drainage patterns in the large slope controls. The soil is shallow, at times barely covering the rock strata beneath, so that one marvels at the yield of massive forest, for if cleared, the thin layer of soil would undoubtedly soon be eroded to bare rock surfaces.

CLIMATIC FEATURES

As a whole, Indiana is more or less a level plain, with moderate relief in the dissected unglaciated south-central portion, but climatic expressions, i. e. in rainfall and temperature, are not so uniform as might be expected, especially when extremes are considered. Visher (16) shows that the Orange county area is well favored with length of growing season, especially also with respect to lower limits of the extremes, and total rainfall for the year is abundant. However, in a region of numerous facets of slopes, as in Orange county, the service of rainfall is strained when translated into available soil moisture, especially in rain-poor seasons. Orange county receives an average of 43 inches of rainfall annually, which is high for the state, but during the critical hot month of July it, as well as most of the southern part of Indiana, has too little rainfall to insure successful farming. Since forests developed luxuriantly in this same region, the way is pointed to the crop which by the laws of nature are intended for the moisture-dissipating, dissected region, with poorly distributed summer rains. In the necessary economy of water in the thin carpet of soil, forest cover prevents run-off and reduces evaporation loss. Tables I-III give evidence of the effectiveness of such a plant cover.

HISTORY OF THE TRACT

Since 1816 the property has been in the Cox family. The original purchaser was Joseph Cox who came to Indiana from eastern Tennessee. He died in 1838, but the forest and land continued in custody of the family. In the third generation was another Joseph Cox who had an almost fanatical love for and devotion to the forest crowding to the very door of the wide-eaved farmhouse in the valley, his boyhood home. It was to him a sacred heritage which had been preserved in its primeval majesty and beauty by his ancestors. In 1880 he was given charge of the estate and consistently and persistently resisted the ever-mounting offers of lumbermen and timber scouts, even to the extent of suffering poverty and worries of debt. Death claimed this guardian of the forest on December 19, 1940.

Upon petition of the heirs, the court ordered Mr. Arthur Farlow, administrator, to sell the property to liquidate the estate. In compliance with this order the trees were sold to a lumber company. The Meridian Club of Paoli had earlier made an effort to raise money to preserve the forest, and even at this crucial hour the club, under the leadership of their chairman, Mr. Raymond Stout, made another attempt to preserve the Cox woods, but time appeared too limited to raise money sufficient to meet the cost, and so the trees were sold to a lumber company. The company agreed to sell back if within a few months money sufficient for the purchase could be raised. The Meridian Club intensified its efforts to secure subscriptions. At this time the Pioneer Mothers' Memorial Association voted a sum of $5,900.00 towards purchase of the forest with the proviso that it be named INDIANA PIONEER MOTHERS' MEMORIAL FOREST. At the same time Dr. J. Alfred Hall of the U. S. Forest Service made an urgent plea to the National Forest Reservation Commission for funds. His plea was successful, half of the sum necessary to purchase the tract was granted, with the stipulation that it be controlled by the Forest Service. The dream of Joe Cox had come true, the trees would stand.

Fitting into the structure of this drama must be considered the men who helped to set the stage for the enactment of the scenes which followed. These are the supervisor of all National Forest projects in Indiana, Mr. R. H. Grabow and his associates whose enthusiasm on the initial visit to the forest, fired accompanying newspapermen, such as Maurice Early of the *Indianapolis Star*, Stephen G. Noland of the *Indianapolis News*, and Clyde A. Taylor, correspondent for Indianapolis and Louisville papers, whose articles and editorials spread the interest to and fired the enthusiasm of the reading public for the preservation of the woods, and the whole combined effort culminated in the Memorial Forest. For a detailed account of the history see the article by Andrew H. Hepburn (8) in the *Saturday Evening Post.*

METHODS

The usual procedure of using the 100 square meter quadrat as sampling unit was followed in this study. According to Cain (4) this unit is more than sufficiently large to insure accurate returns in a mature woods. A stout cord, measured off in four 10-meter sections, each section being provided with a loop, served as means of delimiting the quadrat. The loop could easily be slipped over corner stakes. Wooden calipers were used to measure the DBH. of all stems one inch or over in diameter. Stems below one inch DBH. but at least three meters in height were tabulated for study of dynamics in reproduction. Fifty quadrats, each separated from the preceding by a ten-meter skip, were studied in the mature stand. Ten quadrats were studied in a 160-meter-wide strip which had been levelled by a cyclone in 1897 and since then had been left to a natural re-establishment, a similar number in a dense stand of young trees which recently re-occupied a fallow field and old orchard, and a like number were taken on one of the wide ridge tops (table II). The various tabulations seemed essential to include all habitat types, stands in various stages of development, and the total number of species participating in the economy of such a forest. In the first three types of stands an eighth-acre plot each was studied. The tabulation procedure was similar to that described previously for the quadrat sampling.

RESULTS

The vegetation cover of woody species in the forest primeval as shown by 50 100-square-meter quadrats is divided into 20 species of tall trees, 4 of small trees, and 6 of climbers or lianas; a total of 37 woody species in the sociological complex. The crown cover is controlled chiefly by *Acer saccharum* (F. I. 100%) and *Fagus grandifolia* (F. I. 82); while *Fraxinus americana* and *Ulmus fulva* have a high F. I., the stems are chiefly in the small size-classes, indicating good reproduction but high mortality in the youthful stage; the same is true, perhaps even to a higher degree, for *Morus rubra. Liriodendron tulipifera* (F. I. 28), and *Juglans nigra* (F. I. 34) are clannishly segregated at the lower part or foot of slopes, where moisture is no doubt provided most abundantly by gravity movement. To a marked degree the various genera and species are distributed along belts determined by location on the slope (table III). The succession from the ridge to the trough of the valley is: Quercus-Carya-*Acer saccharum,* to Fagus-Liriodendron, and finally Fagus-Juglans, with some overlapping of the character species of progressively higher belts. In disturbed areas there is reversal to the drier ridge top type of forest with greatest reduction in Fagus. For the forest as a whole Fagus and Acer have the highest F. I. and density, but Juglans and Liriodendron combined almost equalled the former two dominants in total basal area (table I). The most common second layer tree is *Cornus florida,* but it, too, has low frequency and density, indicating that in a closed stand of mature forest, the second layer is not so well expressed. The most widely distributed shrub is *Asimina triloba,* with a F. I. of 72% and high density (453 stems) in the small-size stems. While 6 species of climbers and lianas were represented, none has a high F. I., the most common being *Rhus radicans* (F. I. 50%). This is very likely too low for the species because its presence could be observed only on trunks of trees, and the abundance figures indicate only the number of trees on which the plant appeared, and not the actual number of stems present.

The Cox woods presents in its gross aspects four types of stands, of which the ridge top and slopes of a steep upland support comparatively undisturbed forest (tables I and III); the narrow strip of approximately 160 meters in width, representing vegetation of 45 years development on a wind-swept site (table II), and a recently invaded fallow field and orchard. It seemed essential to make a special survey of the forest on the upland crest because it appeared to diverge somewhat from the typical climax mixed hardwoods towards the oak-hickory type. These tendencies are best expressed by the basal area figures (table III). If the totals for basal areas of Carya and Quercus on the ridge are compared with those of Fagus and Acer, the former have more than double the number of square inches in their basal area than the latter. Needless to say, the two sites of the successional interest should be studied separately for various reasons. The complexity of the deciduous forest has been stressed sufficiently in many papers to warrant elimination of useless repetition of detail here.

The selective power of habitat is also indicated by the fact that of the 46 species entering into a survey of ten quadrats each in the 4 habitat sites (table II) only 11 are present in all 4. The young forest has approximately 20% more species than the association complex of the forest primeval (table II).

Of chief interest are the dynamics operating in a forest to bring about perpetuation of a certain forest-cover type. The importance of certain species is not always the same in stages of succession as in the forest primeval (tables I, II). Thus, Fagus is almost entirely absent in the narrow strip of wind-swept area, but its representation is comparable to the forest primeval in the early succession on the lower-lying, more moist, fallow field. Water, to all appearances, is the one important single factor determining the invasion by such species as *Fagus grandifolia, Liriodendron tulipifera* and *Juglans nigra*. The latter two show abundant reproduction in the fallow field, are but sparingly found in the wind-swept strip and on the ridge top, and in the forest primeval occupy rather restricted smaller areas on the mid-slope and foot of the ridge (table II). *Acer saccharum*, on the other hand finds all these habitats within the range of its moisture requirements. Species entering into the survey of all the various habitat sites are distributed according to the following forms: 28 species of tall trees, 7 of small trees, 7 of shrubs, 6 of climbers and lianas; a total of 48 woody species.

COMPARISONS OF VARIOUS AREAS OF FOREST PRIMEVAL IN INDIANA

In summary form table IV shows comparisons of 7 small tracts of forest primeval which represent climatic climax in Indiana, and are well scattered over the state, including the following counties: Posey, Orange, Dubois, Lawrence, Bartholomew, Franklin, Parke, and Kosciusko. Not only is the association of species similar, and the dominants of the crown cover identical, but also the F. I. and density of the dominants are very similar. Exception to this is found in Nash's woods in Dubois county (Cain, 4). The data from this last-named woods reflect several unusual features which make one skeptical as to its real status. For a typical forest primeval there is too large a number of woody species in the D and E frequency classes, too much prominence of Sassafras, and too many stems of trees per acre. Since size-classes are not given, it is impossible to judge the stage of maturity, or post maturity, of the stand, but the factors just named indicate disturbance of mature crown cover.

DISCUSSION

Most types of broadleaved crown cover of the eastern deciduous forest are climatically favored in Indiana, but the ultimate under optimum mesophytic soil moisture conditions is the mixed mesophytic forest, with great prominence of Fagus and Acer. Yet it is not the most prevalent type in Indiana. As Potzger and Friesner (13) pointed out after a voluminous collection of data in central Indiana, this type cover occupies primarily north-and east-facing slopes, but the same association will control on well-drained loam soil in the northern part of the state (See record from Kosciusko county in table IV). The composition of the Cox woods is very similar to the forests on the north- and east-facing slopes in counties of central-southern Indiana, and we feel justified to say that it is a fine example of the typical climatic climax forest of Indiana. The sensitively balanced nature of mixed mesophytic crown cover with the more xerophytic oak-hickory type was pointed out by Potzger and Friesner (13) and is supported by the somewhat greater prominence of Carya and Quercus on the ridges (table II), as well as in the wind-swept strip (table II) of the Cox woods, but especially by the marked decline of Fagus in these less favorable sites. The removal of the protecting crown cover by the storm very likely increased evaporation loss and thus reduced available soil moisture. As Friesner and Potzger (7) found in a study of a number of sites of these two forest-cover types, evaporation rate is higher and soil moisture lower in the oak-hickory than in the mixed mesophytic hardwoods during nearly all of the spring and summer season. In a specific atmometer study involving this phenomenon, Potzger (11) records 60% greater water loss on south- than on north-facing slopes in Monroe county. Fagus is a sensitive indicator species in the tree stratum along the tension zone between the oak-hickory and mixed mesophytic hardwoods (table II), while *Acer saccharum* is more drought-resistant and invades even the oak-hickory habitats. This was also observed by Potzger (10) in the forests of Monroe county. Fagus, however, more readily invades wet lowlands than Acer.

One is perhaps justified to say that in the deciduous forest young stands of each forest succession are characterized by larger number of stems over 1 inch DBH. per unit area than the mature forest, and also by more species entering into the association complex, for early invaders of old fields persist for a time as relics in a stand gradually developing into its climax cover. In a study made by Potzger and Friesner (12) in Dubois county, this was still the status after a period of 75 years. In that forest the young stand had 33% more woody species than the mature forest. To a certain extent the age and vitality of a stand can be inferred from the number of stems per acre. For that reason 3 eighth-acre plots were tabulated in the present study: in the forest primeval (a); wind-fall strip (b); and fallow field (c) which marked stands of different age. The results were as follows:

	Stems below 1 inch DBH.	Stems above 1 inch
a.	119	39
b.	12	61
c.	82	181

This correlates well with the number of stems in forest primeval of the northern hardwoods type in Wisconsin, where such stands had between 38 and 40 stems per eighth-acre. Moronson (as quoted in Braun-Blanquet, p. 11) found a ratio of 1:2000 between mature and ten-year old stands of beech forest in Russia. The Cox woods has about 290 stems more per hectare (2.6 acres), and supports considerably less in the young stand than the mature forest in Russia.

Number of stems per acre reported by Auten as characteristic for a mature forest also agrees with our findings, both in the Cox woods and in stands of forest primeval in the northern hardwoods. This varies between 220 and 280 stems. For this reason it seems that Nash's woods were not a typical forest primeval. Cain (4) reports 422 stems per acre. Such a high number of stems reflects rather a disturbed forest in late succession. This condition is further indicated by the high F. I. and abundance of Sassafras, as well as by the large number of species in C and D frequency groups. We consistently found such characteristics a feature of disturbed stands. Cain (4) states that of the 25 acres studied only 15 were forest primeval, which evidently means that the study as such is not reflecting the true status in a forest primeval, but is blurred by the 10 acres of disturbed forest, and that the non-conforming features in the sociology are evidently caused by tabulations in the part of the stand which was in secondary succession.

Auten (1) found in the 22 stands studied only one tree over 4 feet in diameter. We can report two stems in excess of such diameter. In the Cox woods is a huge *Fraxinus biltmoreana*, 58 inches DBH., and in the woods in Kosciusko county stands a *Quercus macrocarpa* which Deam (5) calls the largest tree in Indiana. In 1926, it measured 85 inches DBH. This introduces again the erroneous conception which still is held by many persons that the forest primeval was constituted of large stands of mostly massive trunks of trees. In 1934 Potzger and Friesner (12) expressed the opinion that the frequently pictured forest primeval of uniformly huge trees was in reality a forest where trees were mostly 30 to 32 inches DBH., and stems in excess of such diameters were the exception rather than the rule. In the Mauntel oak-hickory stand only 6 stems in 50 100-square-meter quadrats measured 30 to 32 inches DBH.

One misses in the Cox woods the well-expressed second-layer stratum of small trees which is so frequently reported for forests of Indiana. The poorly-expressed second-layer stratum in the Cox woods points to conditions similar to those in the stand at Turkey Run, as reported by Esten (6). There only Carpinus has F. I. of class B (21-40%). If Cain (4) is correct in his statement that the F. I. also indicates density, then we would hardly be justified to speak of a "well-expressed" second-layer stratum when the small trees are all in class A frequency.

As stated previously, in a general comparison of dominants the sociology of the Cox woods is closely similar to that of forests in central Indiana occupying north- and east-facing slopes. As Cain (4) maintained, the dominant species of a specific association of the crown cover have potentiality to endure a wider range of habitat factors than the various strata of the understory, so that one could subdivide the uniform association of the tree stratum by the second layer trees, shrubs, or as Potzger and Friesner (14) suggested in their study of the herbaceous layer of large numbers of beech-maple, and oak-hickory stands, by the key species of the herbaceous layer. The tree stratum of the 7 stands listed in table IV, except Nash's Woods, is almost identical, but the small tree and the shrub layers differ at times widely. A comparison of the small-tree and shrub strata in the 7 stands listed in table IV discloses the following:

Small tree strata: Cercis-Cornus-Carpinus in Nash's and Donaldson's woods; Cornus-Ostrya in Franklin county; Carpinus in Turkey Run; and Ostrya in the stands at Stoney Lonesome and in Kosciusko county. A well-expressed second-story tree-layer was wanting in Cox woods. Shrub strata were: Asimina-Lindera-Smilax-Sambucus in Nash's woods; Asimina-Lindera-Smilax in Cox woods; Asimina in Kosciusko county; and Lindera in Donaldson's woods. Well-expressed shrub layer was wanting in the areas at Stoney Lonesome, Turkey Run and in Franklin county. Finer differentiation of the various stand characteristics could be made if the moss flora were used as indicators.

The similarity of dominants and their F. I. (table IV) in stands of forests primeval representing nearly every section of Indiana is very significant with respect to the climax for Indiana where optimum mesophytic conditions prevail. In the dissected unglaciated portion it is found on north- and east-facing slopes, in the till plain region it finds expression on better drained soils. Variation to a drier habitat increases the oak and hickory associates in the crown cover, while change to a more moist habitat adds Liriodendron, *Ulmus americana, U. racemosa, Celtis occidentalis* and *Fraxinus americana.* In the forest cover types suggested by the Society of American Foresters, the Cox woods corresponds to type 57, beech-sugar maple, but grading into type 58 with its associates of Liriodendron, *Juglans nigra, Fraxinus americana* and *Ulmus fulva.* For that reason the Cox woods differs with respect to basal area of trees in the crown cover from conditions prevailing in most stands studied by Auten (1) who reports that two species usually make up most of the basal area. In the Cox woods Juglans and Liriodendron, species preferring a moist habitat, combined have a basal area almost totalling that of Fagus and Acer combined (table I). However, in frequency and density the latter two species decidedly outclass the former two. The Society of Foresters designates for this type the following status, "Climax while moisture conditions remain stable." It is also described as one of the most important types from northeastern Ohio to eastern Indiana. The habitat is given as morainal hills and lower slopes of valleys. To this we can specifically reply that in the unglaciated part of Indiana it finds expression only on north- and south-facing slopes, extending upward to within the very crest of the ridges.

Predictions of future crown cover is a favorable topic in many studies of this nature, prompted usually by the prolific reproduction of *Acer saccharum* and *Fraxinus americana, F. lanceolata,* or *F. biltmoreana.* As Cain (3) expresses it, the density of reproduction of a species says very little as to importance of the species in the arboreal layer of the future forest. Potzger and Friesner (12) interpreted the abundance of Fraxinus in the young tree group, and its absence in the larger size-classes as indicative of high viability of seeds of this species but of poor survival after a few years of growth.

It is also quite striking that the mature forest of the present study as well as the Mauntel woods (12) have decidedly more stems in the small-size classes than either of the developmental stands (table II) have. One can readily see why that should be the case. Dense stands of young trees occupy not only all available sources of light but their roots are clustered closely to the surface, laying claim to the available soil moisture and so making it difficult for seedlings and small trees to become established. In this manner develop the even-aged stands, as well as the uniform maturity and decline of a forest primeval. The Cox woods is mature, many of the old giants are on the decline, as dead branches in the crown indicate, but it is encouraging to know that this woods will not suffer from "cleaning up," but be permitted to develop and die naturally according to the laws which made its establishment possible long before civilized man looked upon it. In that way can the balanced relationship continue between plant and animal life, especially between those involved in the decadent stage of the trees, including such rare birds as the great pileated woodpecker whose sonorous call and loud-ringing hammer beats sounded through the woods during the days the survey was made. We still need more to study Nature at work in order to become efficient in managing forest and land according to the laws by which they operated when man first interfered. Hepburn (8) writes that the Cox woods is to be "preserved as a forest museum." From the viewpoint of the ecologist we prefer to have it considered and used as one of Nature's laboratories without interference in the natural laws, and elimination of "cleaning up," so that long-time studies on permanent quadrats could be made on succession, survival, reproduction, the influence of the still elusive microclimate of fallen trees and decaying logs. The higher F. I. of Liriodendron in the young stand and lesser representation in the forest primeval would be one phase of such a "laboratory experiment" already set up, and worthy of closer observation.

SUMMARY

1. Presented in this paper are results of a study on the phytosociology operating in Cox woods, Orange county, Indiana—a small stand of forest primeval.
2. Results are based on 100-square-meter quadrat studies involving areas of forest primeval on east-facing slopes and ridge top, as well as two smaller areas of early and late succession following disturbance by windstorm and man.
3. The forest primeval on the slopes is typical climax mixed mesophytic forest in which *Acer saccharum* and *Fagus grandifolia* play the most important role.
4. Associated with these two prominent dominants are 18 additional tall and 4 small-sized broadleaved species.
5. A well-developed small-tree understory is lacking.

6. The most common shrub is *Asimina triloba* with F. I. 72%.

7. The co-dominants of the crown, *Juglans nigra* and *Liriodendron tulipifera* are aggregated rather clannishly at moist depressions along the slopes and at the foot of ridges.

8. Comparison is made with the sociology in 6 other stands of climax forest in various parts of Indiana. The crown cover associates are very similar throughout except in Nash's woods (Dubois county). The latter stand grades into the wet lowland type of forest, and several sociological features indicate considerable disturbance in the crown cover.

9. The ridge and wind-fall strip, now in stage of late succession indicate reduced available soil moisture, at least during the period of establishment, by sharp reduction in importance of Fagus and increase in species of Carya and Quercus.

10. The old field succession stand has 20% more species participating in the crown cover than the more mature forest.

11. Successional stages show reduction in abundance of trees below one inch DBH. from that present in the mature stand.

12. Number of stems per unit area decrease with increase in maturity of stand.

13. Cox woods is considered a fine example of climatic climax forest for Indiana under optimum mesophytic conditions.

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TABLE I

Size-classes of various species in 50 quadrats. Forest primeval.

Species	Size in inches DBH								Basal area sq. in.	Total stems 1 in. or over	F. I.
	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	31-40			
Acer saccharum	517	120	64	42	8		5		5566.92	239	100
A. rubrum	1										2
Asimina triloba	453	3								3	72
Aralia spinosa	1	1								1	4
Carpinus caroliniana var. virginiana	13	2							3.94	2	24
Carya cordiformis	5	1							3.4	1	12
C. glabra	1	2							3.93	2	6
C. ovata	7		3				1	1	1406.65	5	16
Celastrus scandens	4										2
Celtis occidentalis var. crassifolia	9	4	2						19.64	6	16
Cercis canadensis	15	3	2						18.85	5	18
Cornus florida	38	20		1						21	32
Evonymus atropurpurea	12								10.21		12
Fagus grandifolia	114	27	4		3	7	14	4	11289.34	59	82
Fraxinus americana	439	8	2	2	1	1	1		1025.73	15	86
Gymnocladus dioica						1			254.47	1	2
Hydrangea arborescens	2										2
Juglans nigra	13			1	1	2	4	4	6947.43	12	34
Lindera benzoin	331										26
Liriodendron tulipifera	10						12	3	9397.16	15	28
Menispermum canadense	2										2

TABLE I—(Continued)

Species	Below 1 in.	Size in inches DBH 1-2	3-5	6-10	11-15	16-20	21-30	31-40	Basal area sq. in.	Total stems 1 in. or over	F. I.
Morus rubra	39	3		1					80.90	4	52
Nyssa sylvatica	1										2
Ostrya virginiana	2	1	3						27.50	4	4
Prunus serotina	14	2							1.57	2	18
Quercus alba	1		1	4	1	1		2	3451.83	9	16
Q. borealis var. maxima	3	1		1				1	64.41	6	10
Q. muhlenbergii			1			1			208.13	2	2
Q. velutina					1		1		606.33	2	4
Rhus radicans	63										50
Sambucus canadensis	4										6
Sassafras albidum	11				1	1			359.71	2	16
Smilax hispida	29										10
S. rotundifolia	102										28
Ulmus fulva	309	10		1					49.47	11	66
Vitis sp.	6	1	1							2	12

TABLE II

Size-Classes and frequency of woody species present in four different areas. Based on 10 quadrats of 100 square-meters each. a. ridge top; b. windfall area; c. fallow field; d. forest primeval.

Species		Size-Classes in inches DBH								Basal area sq. in.	Total stems 1 in. or above	F. I.		
		Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30			Below 1 in.	1 in. or above	Both Sizes
Acer saccharum	a	85	65	28	15	1				1141.85	109	90	100	100
	b	78	32	32	3	1				486.94	68	100	80	100
	c	125	118	40						610.47	158	100	100	100
	d	151	47	10	7	2				717.06	66	90	100	100
Aralia spinosa	a													
	b													
	c													
	d		1								1		10	10
Amelanchier canadensis	a													
	b	2											20	20
	c													
	d													
Asimina triloba	a	63										60		60
	b	12	2								2	20	10	20
	c	10										40		40
	d	56	1								1	80	10	80
Betula nigra	a													
	b													
	c			1						19.63	1		10	10
	d													
Carpinus caroliniana var.	a													
	b	2										10		10

TABLE II—(Continued)

Species		Size-Classes in inches DBH								Basal area sq. in.	Total stems 1 in. or above	F. I.		
		Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30			Below 1 in.	1 in. or above	Both Sizes
virginiana	c	7	3								3	50	20	50
	d	4	1								1	40	10	40
Carya cordiformis	a	4										20		20
	b													
	c	1										10		10
	d	1	1							3.14	1	10	10	20
C. glabra	a					3				511.29	3		30	30
	b		1	5	2					130.46	8		50	50
	c				3					165.71	3		20	20
	d		1							.79	1		10	10
C. ovata	a				2	1				255.26	3		20	20
	b		2	5	11					517.58	18		80	80
	c	3	3	13	9					483.01	25	30	80	80
	d	5		1						7.07	1	40	10	40
Celastrus scandens	a													
	b													
	c	3										30		30
	d													
Celtis occidentalis var. crassifolia	a	5										20		20
	b													
	c													
	d	4	1	1						7.86	2	20	10	20
Cercis canadensis	a			1	1					40.84	2		20	20
	b													
	c	5	4		1					175.14	5	20	40	50

TABLE II—(Continued)

Species		Size-Classes in inches DBH								Basal area sq. in.	Total stems 1 in. or above	F. I.		
		Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30			Below 1 in.	1 in. or above	Both Sizes
	d	2	2	1						11.	3	10	10	20
Cornus florida	a	2										20		20
	b	6										10		10
	c	2	4	1						20.42	5	10	40	40
	d	5	1							3.14	1	40	10	50
Diospyrus virginiana	a													
	b													
	c		1	2						22.78	3		30	30
	d													
Evonymus atropurpurea	a													
	b		1								1		10	10
	c													
	d	7										30		30
Fagus grandifolia	a	5	5	4						51.83	9	20	40	40
	b													
	c	5	5	2	1					66.75	8	40	50	70
	d	21				1	1	2	1	2259.59	5	50	40	50
Fraxinus	a	93	7							146.09	7	40	20	40
americana	b	6		2	3					205.78	5	50	20	60
	c	33	9							11.77	9	100	50	100
	d	65	4							5.5	4	90	30	90
F. biltmoreana	a								1	2642.09	1		10	10
	b													
	c													
	d													

TABLE II—(Continued)

Species		Size-Classes in inches DBH								Basal area sq. in.	Total stems 1 in. or above	F. I.		
		Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30			Below 1 in.	1 in. or above	Both Sizes
Hydrangea	a													
arborescens	b													
	c	5										10		10
	d													
Juglans nigra	a				5	2				527.57	7		50	50
	b				1	1				183.	2		20	20
	c	2	2	3	1					91.9	6	20	40	50
	d	6				1				153.94	1	20	10	30
Juniperus virginiana	a	2										10		10
var. crebra	b													
	c	31	2	1						23.56	3	100	10	100
	d													
Lindera benzoin	a													
	b													
	c													
	d	1										10		10
Liriodendron	a	1										10		10
tulipifera	b													
	c	15	20	16	10					670.78	46	70	100	100
	d	9						3	1	2420.60	4	10	30	40
Malus coronaria	a													
	b													
	c	1	3	2						29.06	5	10	30	30
	d													
Menispermum	a													

TABLE II—(Continued)

Species		Size-Classes in inches DBH								Basal area sq. in.	Total stems 1 in. or above	F. I.		
		Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30			Below 1 in.	1 in. or above	Both Sizes
canadense	b													
	c													
	d	2										10		10
Morus rubra	a	6		1						12.57	1	30	10	30
	b	2										10		10
	c	2	3	1						11.78	4	20	40	60
	d	10	1							.79	1	40	10	40
Nyssa sylvatica	a													
	b			2						32.20	2		10	10
	c	1										10		10
	d													
Ostrya virginiana	a			1						7.07	1		10	10
	b	1										10		10
	c	2										20		20
	d	2										10		10
Platanus occidentalis	a													
	b													
	c				1					28.27	1		10	10
	d													
Populus grandidentata	a													
	b													
	c		1							.79	1		10	10
	d													
Prunus americana	a													
	b													

TABLE II—(Continued)

Species		Below 1 in.	Size-Classes in inches DBH						Above 30	Basal area sq. in.	Total stems 1 in. or above	F. I.		Both Sizes
			1-3	3-5	6-10	11-15	16-20	21-30				Below 1 in.	1 in. or above	
	c		1							3.14	1		10	10
	d													
Prunus serotina	a													
	b					1				113.1	1		10	10
	c													
	d													
Quercus alba	a	1			2	1	3	1		1410.57	7	10	50	60
	b	2		1	6	3				447.68	10	20	50	60
	c	3										30		30
	d				1				2	2488.93	3		30	30
Q. borealis var. maxima	a													
	b				3	2	1			673.88	6		40	40
	c	1										10		10
	d													
Q. muhlenbergii	a						1			226.98	1		10	10
	b													
	c													
	d													
Q. velutina	a													
	b				2	3	1			768.9	6		40	40
	c	2										20		20
	d							1		452.39	1		10	10
Rhus copallina	a													
	b													
	c	7	4								4	30	20	30

TABLE II—(Continued)

Species		Size-Classes in inches DBH Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30	Basal area sq. in.	Total stems 1 in. or above	F. I. Below 1 in.	1 in. or above	Both Sizes
	d													
R. radicans	a													
	b													
	c	1										10		10
	d	18										50		50
Rubus occidentalis	a													
	b													
	c	1										10		10
	d													
Sassafras albidum	a													
	b													
	c	2	5	3						35.34	8	20	40	50
	d	2										20		20
Smilax hispida	a	5										?		?
	b													
	c													
	d	18										30		30
S. rotundifolia	a													
	b	2										10		10
	c													
	d	53										50		50
Ulmus americana	a	2										20		20
	b	5	2							3.93	2	20	20	30
	c	8										50		50
	d													

TABLE II—(Continued)

Species		Below 1 in.	Size-Classes in inches DBH						Above 30	Basal area sq. in.	Total stems 1 in. or above	F. I.		
			1-2	3-5	6-10	11-15	16-20	21-30				Below 1 in.	1 in. or above	Both Sizes
U. fulva	a	33	1		1	1				146.09	3	40	30	50
	b	53			1	1				141.37	2	70	20	80
	c	14	8	1						13.35	9	60	30	70
	d	81	4							3.14	4	70	10	70
Tilia americana	a													
	b				2					66.75	2		10	10
	c													
	d													
Vitis sp.	a	1										10		10
	b	1										10		10
	c	5	8								8	40	60	60
	d	2										10		10

Total number species—46
Common to all sites—11

TABLE III

Significant species present, size-class and F. I. of woody plants along various belts on the slope. Ten 100-square-meter quadrats each. a. Ridge; b. Upper slope; c. Mid-slope; d. Foot of slope.

Species		Size-Classes in inches DBH								Basal area sq. in.	Total stems 1 in. or over	F. I.		
		Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30			Below 1 in.	Above 1 in.	All Sizes
Acer saccharum	a	85	65	28	15	1				1141.85	109	90	100	100
	b	151	47	10	7	2				717.05	66	90	100	100
	c	170	29	15	8	3				973.05	55	90	90	100
	d	111	13	13	9					635.35	35	90	100	100
Asimina triloba	a	63										60		60
	b	56	1								1	80	10	80
	c	23	2								2	40	10	40
	d	17										30		30
Carya cordiformis	a	4										20		20
	b	1	1							3.14	1	10	10	20
	c	1										10		10
	d	1										10		10
C. glabra	a					3				511.29	3		20	20
	b		1							.79	1		10	10
	c	1	1							3.14	1	10	10	20
	d													
C. ovata	a				2	1				255.26	3		20	20
	b	5		1						7.07	1	40	10	40
	c	2										10		10
	d			1				1	1	1379.95	3		20	20
Fagus grandifolia	a	5	5	4						51.83	9	20	40	40
	b	21				1	1	2	1	2259.59	5	50	40	50

TABLE III—(Continued)

Species		Size-Classes in inches DBH								Basal area sq. in.	Total stems 1 in. or over	F. I.		
		Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30			Below 1 in.	Above 1 in.	All Sizes
	c	29	11				1	3	3	4604.86	18	70	80	100
	d	22		1	1		2	5		2347.56	9	50	60	90
Fraxinus americana	a	93	7							10.21	7	40	20	40
	b	65	4							5.5	4	90	30	90
	c	116					1			254.47	1	90	10	90
	d	55	3	2	2	1		1		725.71	9	50	40	70
F. biltmoreana	a								1	2642.09	1		10	10
	b													
	c													
	d													
Juglans nigra	a				5	2				527.57	7		50	50
	b	6				1				153.94	1	20	10	30
	c	2										20		20
	d	5					1		4	4573.17	5	20	40	50
Lindera benzoin	a													
	b	1										10		10
	c													
	d	199										50		50
Liriodendron tulipifera	a	1										10		10
	b	9						3	1	2420.60	4	10	30	40
	c	1						3	2	3739.29	5	10	40	50
	d							1		706.86	1		10	10
Morus rubra	a	14		1						12.57	1	30	10	30
	b	10	1							.79	1	40	10	40
	c	9	1		1					79.33	2	70	20	70

TABLE III—(Continued)

Species		Size-Classes in inches DBH								Basal area sq. in.	Total stems 1 in. or over	F. I.		
		Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-30	Above 30			Below 1 in.	Above 1 in.	All Sizes
	d	8										70		70
Quercus alba	a	1			2	1	3	1		1410.57	7	10	50	60
	b				1				2	2488.93	3		30	30
	c				1					38.48	1		10	10
	d	1	1							28.27	1	10	10	20
Q. borealis var. maxima	a													
	b													
	c	3			1					63.62	1	20	10	30
	d													
Q. muhlenbergii	a						1			226.98	1		10	10
	b													
	c													
	d													
Q. velutina	a													
	b							1		452.39	1		10	10
	c													
	d													
Ulmus fulva	a	33	1		1	1				146.09	3	40	30	50
	b	81	4							3.14	4	70	10	70
	c	131	1							.79	1	60	10	60
	d	53	4							3.14	4	90	30	90

TABLE IV

Showing F. I. of species present in Cox Woods which are also present in six stands of forest primeval in various parts of Indiana. (a) F. I. stems below 1 inch; (b) above; (c) all sizes.

Species		Cox Woods 50	Donaldson Woods 25	Stoney Lonesome 20	Franklin county 50	Kosciusko county 50	Turkey Run 25	Nash Woods 25
Acer rubrum	a	2	64	10		2		
	b		40	20		2		
	c	2		30		4		
A. saccharum	a	82	56	95	34	76	81-100	
	b	98	68	90	42	94		
	c	100		100	62	98		100
Asimina triloba	a	4	4			46	1-20	
	b	76				34		
	c	76				56		68
Aralia spinosa	a	2						
	b	2						
	c	24						
Carpinus caroliniana var. virginiana	a	20	36	20	2	4	21-40	
	b	4		5	6	18		
	c	24		20	8	20		64
Carya cordiformis	a	10	24		2	14	21-40	
	b	2			2	4		
	c	12			4	18		76
C. glabra	a	2	84	10	8			
	b	4	24	20	20			
	c	6		25	28			68

TABLE IV—(Continued)

Species		Cox Woods 50	Donaldson Woods 25	Stoney Lonesome 20	Franklin county 50	Kosciusko county 50	Turkey Run 25	Nash Woods 25
C. ovata	a	6	12	10	8			
	b	10	44	5	28			
	c	16		15	34			
Celastrus scandens	a	2	20					
	b							
	c	2						36
Celtis occidentalis var. crassifolia	a	12	4			14		
	b	4				12		
	c	16				22		8
Cercis canadensis	a	12	56					
	b	6	4					
	c	18						64
Cornus florida	a	30	88	20	44		1-20	
	b	10	92	30	82			
	c	32		40	86			84
Evonymus atropurpurea	a	12	4					
	b							
	c	12						60
Fagus grandifolia	a	56	20	50	58	34	41-60	
	b	62	48	95	90	68		
	c	82		95	96	78		
Fraxinus americana	a	86	96	5	2	12		
	b	20	48		2	16		
	c	86		5	4	24		
F. lanceolata	a			35	20	2	41-60	

TABLE IV—(Continued)

Species		Cox Woods 50	Donaldson Woods 25	Stoney Lonesome 20	Franklin county 50	Kosciusko county 50	Turkey Run 25	Nash Woods 25
	b				6	2		
	c			35	24	4		100
Gymnocladus dioica	a							
	b	2						
	c	2						4
Hydrangea arborescens	a	2						
	b							
	c	2						
Juglans nigra	a	10					1-20	
	b	20				2		
	c	34				2		12
Lindera benzoin	a	26	28	15	4	2		
	b							
	c	26		15	4	2		72
Liriodendron tulipifera	a	4	24			2	1-20	
	b	24	12	10	14	16		
	c	28		10	14	16		80
Menispermum canadense	a	2	4				1-20	
	b							
	c	2						56
Morus rubra	a	52	28				1-20	
	b	8	8					
	c	52						76
Nyssa sylvatica	a	2	36	15	10		1-20	
	b		20		18			

TABLE IV—(Continued)

Species		Cox Woods 50	Donaldson Woods 25	Stoney Lonesome 20	Franklin county 50	Kosciusko county 50	Turkey Run 25	Nash Woods 25
	c	2		15	24			80
Ostrya virginiana	a	2	24	40	30	42	1-20	
	b	2	12	40	30	30		
	c	4		50	50	54		
Prunus serotina	a	16	48			4	21-40	
	b	2			8	6		
	c	18			8	8		88
Quercus alba	a	2	64	5	2		1-20	
	b	14	72	10	14			
	c	16		15	16			40
Q. borealis var. maxima	a	4	12					
	b	6	12	5	6	4		
	c	10		5	6	4		56
Q. muhlenbergii	a				2			
	b	2						
	c	2			2			
Q. velutina	a			10				
	b	4	4	5				
	c	4		10				
Rhus radicans	a	50	44					
	b							
	c	50						100
Sambucus canadensis	a	6		5		2	1-20	
	b							
	c	6		5		2		76

TABLE IV—(Continued)

Species		Cox Woods 50	Donaldson Woods 25	Stoney Lonesome 20	Franklin county 50	Kosciusko county 50	Turkey Run 25	Nash Woods 25
Sassafras albidum	a	14	68	10			1-20	
	b	4	4	10	15			
	c	16		15	15			88
Smilax hispida	a	10					1-20	
	b							
	c	10						92
S. rotundifolia	a	28	80	15				
	b							
	c	28		15				
Ulmus americana	a							
	b				12	4		
	c				12	4		
U. fulva	a	64	80		2	16	1-20	
	b	14				18		
	c	66			2	32		92
U. racemosa	a					8		
	b					52		
	c					56		
Vitis sp.	a							
	b		4					
	c	12						48

LEMANEA HERBARIUM PACKETS CONTAINING MORE THAN ONE SPECIES

By C. Mervin Palmer

Two important and historic herbarium packets of Lemanea which the writer has examined recently have been found to contain material of two distinct species of the genus. In both cases, one species belongs to the subgenus Sacheria and the other species to the subgenus Eulemanea. These subgenera can be separated from each other very readily (5) and there is no doubt about the presence of two species in both of the herbarium packets under consideration.

One herbarium packet is that of G. H. E. Muhlenberg and contains his number 1563. It is to be found with his herbarium material which is in the care of the Academy of Natural Science of Philadelphia, Pennsylvania. The Lemanea packet is marked "Lemania N S varieg." and is probably that which was collected by Muhlenberg, August 11, 1763, on exposed rock in a river in Virginia. Some of this material apparently was sent to Swartz in Europe and it was then listed by Agardh (1) in 1828 as a new species, "Lemania variegata." Kützing (4), in 1849, lists *L. variegata* Ag. under the heading "Species inquirendae" and describes the plant as "Filis moniliformibus variegatis.—In fluviis Americae borealis."

The packet of Muhlenberg's Lemanea which is with his herbarium material at Philadelphia was examined by the writer in March 1941, and it was found to contain, for the most part, sexual strands of a species belonging to the subgenus Sacheria. The writer considers it to be *Lemanea fucina* (Bory) Atkinson. Two other clusters found in the packet belong to the subgenus Eulemanea and are considered by the writer to be *Lemanea torulosa* Sirodot.

As has been indicated previously (5), Muhlenberg's Lemanea is of great historic interest since it represents the earliest known American collection and record for the genus. The suggestion is found in Sylloge Algarum by DeToni (2) that *Lemanea variegata* Ag. is probably *Tuomeya fluviatilis* Harv. but the study of Muhlenberg's material now shows that it undoubtedly belongs to Lemanea and not to Tuomeya.

The portion of Muhlenberg's material identified by the writer as *Lemanea fucina* (Bory) Atkinson is characterized as follows: Sexual strands arcuate, in small tufts, light brown with blackish nodes (due to spores within); length, 0.5-3.0 cm; diameter of nodes, up to 0.4 mm; internode length, up to 2 mm; branching absent; base, abruptly stipitate. Antheridial papillae are visible on a few of the nodes only (due probably to old age). Papillae protrude slightly and are limited to about three per node. Carpospores abundant, commonly elliptical-oval, greenish, in distinct chains, limited in distribution to the nodal areas. Axial filaments naked. The other portion of Muhlenberg's material, identified by the writer as *Lemanea torulosa* Sirodot is described as follows: Sexual strands in tufts, dark purple-brown to black. No prominent nodes on most of the strands. Two fragments show nodes which appear to have had antheridial rings. Diameter of nodes, 0.8 mm. No spores present. Axial filaments surrounded by other filaments.

The second packet of Lemanea containing two species of the genus is one sent by R. B. Gordon of material collected by him in the Allegheny River near Quaker Bridge, N. Y., on July 21, 1935. It is labelled *Lemanea grandis* (Wolle) Atkinson. The writer has found this packet to contain not only the *L. grandis* but also a considerable amount of *Lemanea fucina* (Bory) Atkinson. Gordon (3) states in his published account of *Lemanea grandis* in New York that *L. fucina* is the only other species of the genus found in that state and it is interesting to find that the two species must have been found growing together at Quaker Bridge. The earlier collection made at the same place by Gordon and which is the one upon which his published article is based, contains material only of *L. grandis*.

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1. Agardh, C. A. Species Algarum. 2(1):1-8. 1828.
2. De Toni. Sylloge Algarum Omnium Hucusque Cognitarum. Vol. IV. Florideae. Sectio. I—Familiae I—XI. Patavii, Nov. 1897.
3. Gordon, R. B. *Lemanea grandis* (Wolle) Atkinson rediscovered after forty years. Bull. Tor. Bot. Club 61:437-439. 1934.
4. Kützing, F. T. Species Algarum. Lipsiae. 1849.
5. Palmer, C. M. A study of Lemanea in Indiana with notes on its distribution in North America. Butler Univ. Bot. Stud. 5:1-26. 1941.

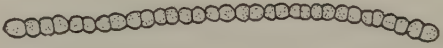
ADDITIONAL RECORDS FOR ALGAE, INCLUDING SOME OF THE LESS COMMON FORMS

By C. Mervin Palmer

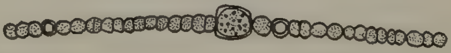
Over a period of several years, the writer has accumulated a record of new locations for several fresh-water algae some of which are not commonly encountered. In some cases the material has been collected and submitted by students and others, from whom permission has been obtained to include such algae in this article. All but three of the forms were collected in Indiana, one was collected in Massachusetts and two are from California. Specimens of all of the forms listed with the exception of *Stichococcus bacillaris* and *Volvox mononae* have been placed in the herbarium of Butler University. All of the text figures shown are made from camera lucida drawings of the material studied. The writer expresses his appreciation to Dr. Francis Drouet for his aid in checking the identification of several of the forms. The twenty-seven algae are listed alphabetically under the name of the class to which they belong.

MYXOPHYCEAE

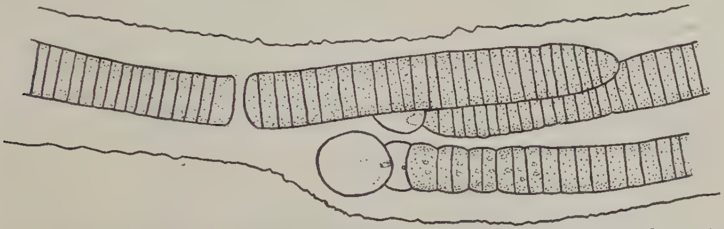
Anabaena constricta (Szafer) Geitler. Collected by C. K. Calvert, November 1, 1932, from the effluent trough of the sewage treatment plant at Indianapolis, Indiana. Very abundant and mixed with sulphur bacteria. Species not previously recorded for Indiana.



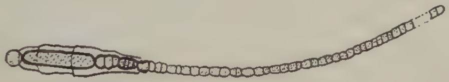
Anabaena viguieri Denis et Frémy. Collected by C. M. Palmer, July 10, 1932, in a pond at a fish hatchery near Martinsville, Morgan County, Indiana. Planktonic. Species not previously recorded for Indiana.



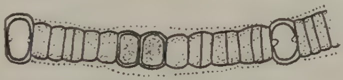
Desmonema wrangelii (Ag.) B. and F. Collected by R. Prettyman, July 30, 1938, in Marble Rock creek, Sequoia National Park, California. Attached to rocks. Under the microscope it has a rather striking and characteristic form with its radiate growth and irregularly but abundantly forked branching. This is a rare alga with reports of it for only about 6 states.



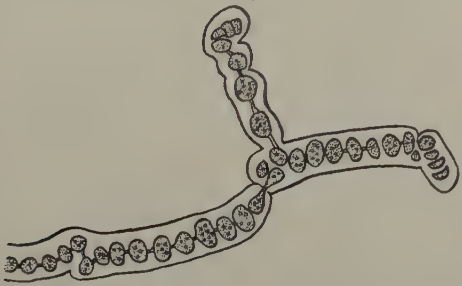
Gloeotrichia natans (Hedw.) Rab. Collected by C. M. Palmer, July 13, 1938, on one of the ponds at the state fish hatchery in Marion County, Indiana. Abundant; attached to larger aquatic plants and also free-floating. The brownish gelatinous beads were irregular in form and variable in size. Species previously reported in Indiana for Monroe and Vigo Counties.



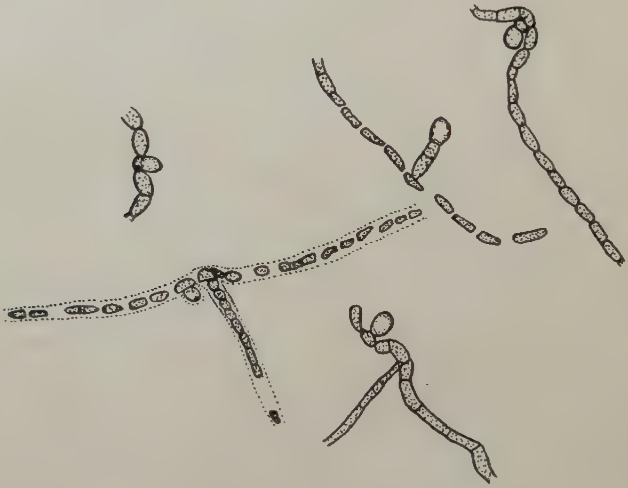
Nodularia spumigena Mertens. Collected by C. M. Palmer, July 12, 1938, in a bog called "Bacon's Swamp," Indianapolis, Indiana. Present in considerable quantity forming a slimy blue-green layer attached to a submerged cardboard box. Species previously reported in Indiana for Knox County.



Stigonema hormoides (Kütz.) B. and F. Collected by R. Prettyman and C. M. Palmer, May 20, 1932, near the shore of Sugar creek in Parke county, Indiana. Attached to wet vertical rock surface. This alga was reported under the name, *Sirosiphon campactus*, for Monroe County in 1926.

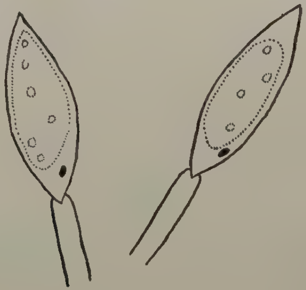


Nostochopsis lobatus Wood. Collected by Winona Welch, July 5 1937, in Saluda creek, Jefferson County, Indiana. Attached to rock in slowly running water. Genus not previously reported in Indiana.

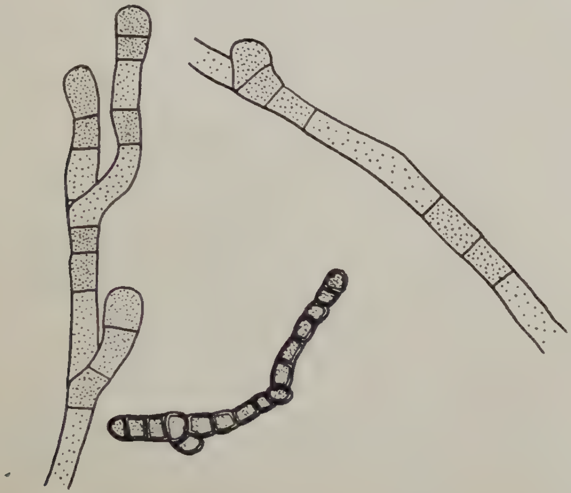


CHLOROPHYCEAE

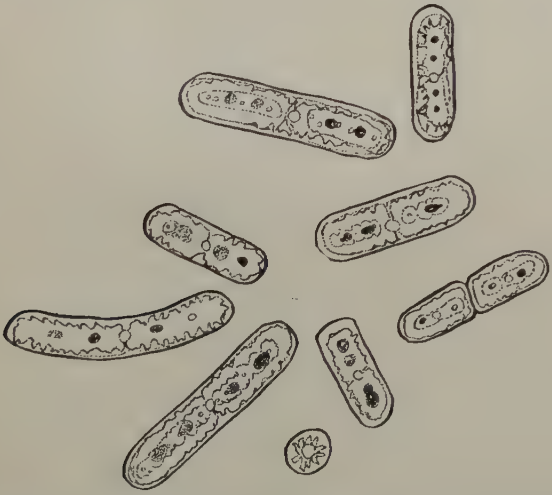
Chlorogonium euchlorum Ehr. Collected by E. Hupp, June 24, 1939, in barnyard pool, Marion County, Indiana. Forming a prominent green bloom. Genus had not been reported previously for Indiana until Lackey (Pub. Health Repts., U. S. 57:253-260) in Feb. 1942 listed it for Dearborn County.



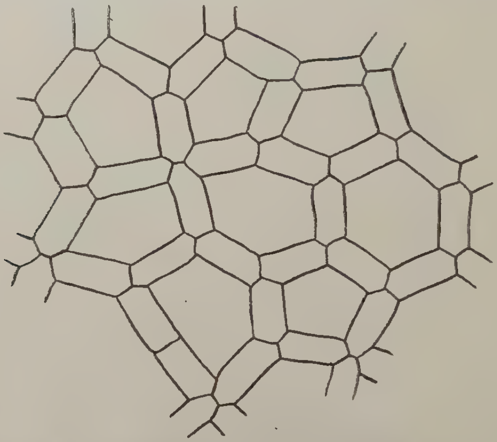
Chlorotylium mammiforme (Balbi) Kütz. Collected by Edna Banta, May 23, 1936, in small stream, 3.5 miles from Brooksburg, Jefferson County, Indiana. Forming papillate, gelatinous crust on rocks. Genus new for Indiana.



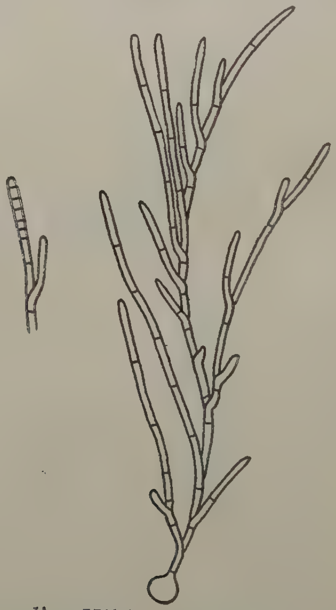
Cylindrocystis brebissonii Menegh. Collected by C. M. Palmer, in 1930 from a small pool beside a stream, near Corydon Junction, Harrison County, Indiana.



Hydrodictyon reticulatum (L.) Lagerheim. Collected by C. M. Palmer, June 15, 1933, in small artificial pond containing stagnant water, Marion County, Indiana. Species previously listed for 7 counties in the state.

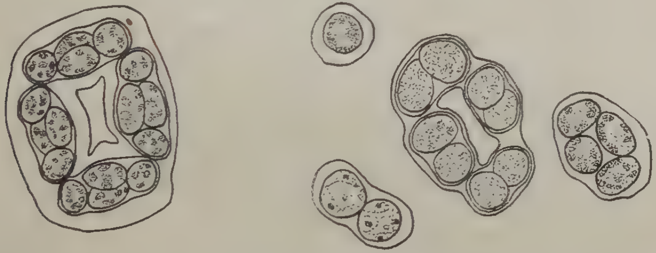


Microthamnion strictissimum Rab. Collected by C. M. Palmer, February 2, 1930, in a small stream on the campus of Butler University, Marion County, Indiana. Although this is one of the filamentous green algae ,it has a record for only 3 counties in the state.

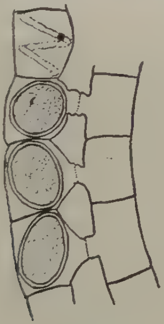


Oocystis novae-semliae Wille. Collected in almost pure growth at two places several miles apart by students of botany at Shortridge

High School, Indianapolis, Indiana, and turned over to the writer by their teachers, Miss E. S. Rawls and Miss M. Campbell. One collection was made from an outdoor fish-pond in a yard in Indianapolis on Sept. 29, 1938. The other was collected a few days later from a pond at New Augusta, Marion County, Indiana. While the material fits the description of *O. novae-semliae,* its most striking character, the aggregation of some of the cells into very regular cubical compound colonies, seems not to be previously described. The cells are held in groups of four by the swollen wall of the mother cells; in turn, these are held in groups of 4 to form the cubical colony which is hollow and open on two of its 6 sides. Due to numerous rod-shaped bacteria attached radially to the outside of the mother cell walls, the alga resembles somewhat the appearance of Bohlinia. The species has no previous Indiana record.

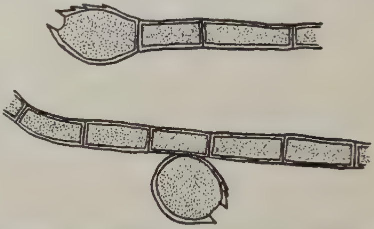


Spirogyra varians (Hass.) Kütz. Collected by C. M. Palmer, May 21, 1932, in Coal creek, Parke County, Indiana.

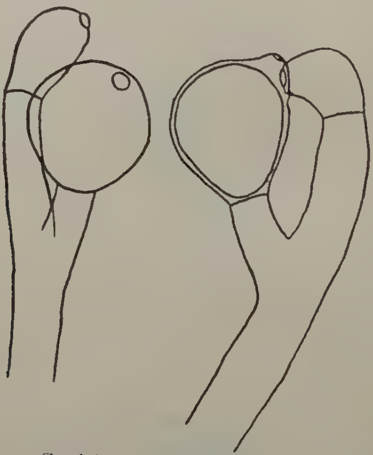


Stichococcus bacillaris Näg. Collected by C. M. Palmer, March 1936, in Monroe County, Indiana. The species is new for Indiana.

Trentepohlia aurea (L.) Martius. Collected by R. Prettyman, April 23, 1932, on dry rock surface, Monroe County, Indiana. Reported for the same county by Andrews in 1926 as *Chroolepus aureus.*

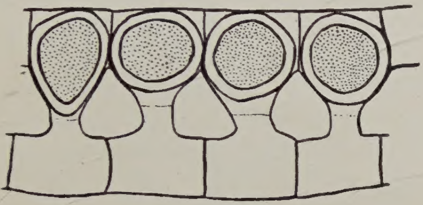


Vaucheria arechavaletae Magn. et Wille. Collected by L. Martens, March 12, 1937, in Monroe County, Indiana, about 3 miles southwest of Bloomington in Maple Hill Pond creek; attached, in running water; abundant. Oogonium and antheridium located on the same long lateral branch, the antheridium at the end of this branch with the oogonium at the end of a side fork of the sexual branch. Oogonium with pore lateral or oblique. No ripe oospores seen. Beak of oogonium extends toward the antheridium which has one opening which is terminal. Diameter of vegetative strands, 22-24 microns. Length of oogonium, 44-61 microns with a diameter of 44-57 microns. Length of antheridium, 33-41 microns with a diameter of 21-23 microns. Reported previously for South America by Wille, in 1884.



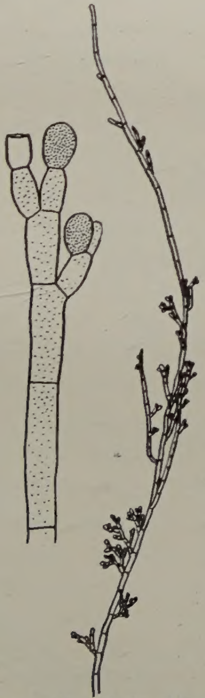
Volvox mononae Smith. Collected by H. G. Nester, September 1932, in pool at state fish hatchery, Marion County, Indiana. No cytoplasmic connections were evident between the protoplasts even after the addition of methylene blue stain. Diameter of colony, 225 microns; diameter of cell, 6 microns.

Zygnema normani Taft. Collected by C. M. Palmer, February 1932, in fish hatchery pool, Marion County, Indiana. Species new for the state.

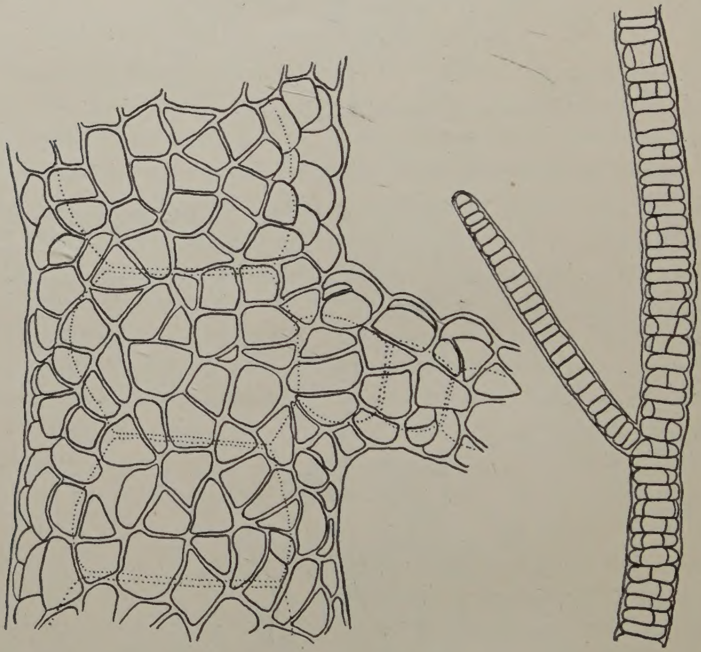


RHODOPHYCEAE

Audouinella violacea (Kütz.) Hamel. Collected by Wm. A. Daily, April 30, 1939, from rock surface beneath a falls in a canyon at Muscatatuck State Park, Jennings County, Indiana. Genus not previously reported for Indiana.



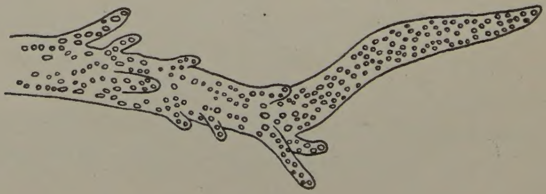
Compsopogon coeruleus (Balbis) Mont. Collected by Hellen Aufderheide, March 16, 1934, from an indoor fish bowl, Indianapolis, Indiana. The alga was attached to Elodea. This alga is a distinctly tropical one and the fact that there were tropical fish in the bowl indicates the probability that the Compsopogon was imported from a more southern habitat. The material appeared to be in excellent condition and some strands were found producing spores. Length of strands, up to 2.5 cm.



Porphyridium cruentum Näg. Collected by Charlene Coffing, May 10, 1934, from greenhouse soil in Marion County, Indiana.

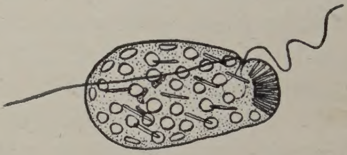
CHRYSOPHYCEAE

Hydrurus foetidus (Vill.) Kirchn. Collected by R. Prettyman, July 28, 1938, at a spring which runs into Silliman creek, Sequoia National Park, California.



CHLOROMONADOPHYCEAE

Merotricha capitata Skuja (Acta Horti Bot. Univ. Latviensis 7:33. 1934). Collected by C. M. Palmer, June 27, 1936, in small numbers in certain shallow parts of a bog called "Cedar Swamp" near Woods Hole, Massachusetts; in subsequent samples it was taken from the bog during the following 5 weeks. This genus, it seems, has not been reported previously in the Western Hemisphere. Skuja described the organism originally from a locality in Latvia. The genus Merotricha Mereschkowsky (Trudy S.-Peterbursk. Obshch. Estestvoispit 8:291-292. 1877; Arch. f. mikrosk. Anat. 16:186. 1878) is based upon material collected in northern Russia; no measurements and but one flagellum are mentioned in the original description of the type species, *M. bacillata* Mereschk. *M. capitata* is a member of the Chloromonadophyceae to which class also belongs *Gonyostomum semen* (Ehrenb.) Diesing, a flagellate abundant in the same "Cedar Swamp" (Drouet and Cohen, Biol. Bull. 68:422-439. 1935). In contrast to Gonyostomum, *M. capitata* is circular in cross-section and has a prominent tuft of trichocysts in the anterior region with flagella inserted laterally just behind the tuft of trichocysts, and contains a rounded rather than 3-angled reservoir. There is no caudus at the posterior end. Like Gonyostomum, it contains bright green chromatophores which turn blue-green when treated with acid and has trichocysts scattered throughout the periphery of the protoplast. Also like that of Gonyostomum, the cell has the property of bursting under very slight changes of external conditions. Measurements of 25 cells indicates that the organisms range from 36-45 microns in length and from 18-25 microns in diameter. This range in linear measurement is greater than that given by Skuja, whose description reads 40-46 microns long and 20-25 microns wide. In the Massachusetts material there are two flagella, a short one extending forward and a longer one extending backward from the opening of the reservoir. On one cell measuring 39 by 22 microns, the two flagella were 31 and 48 microns respectively in length. The forward flagellum is commonly twisted and waving to and fro, while the posteriorly directed flagellum is straight and not so active. Chromatophores are numerous, discoid, about 4 microns in diameter, and bright green. Dark irregular bodies present in the posterior region are possibly reserve food (oil?). Trichocysts are in the form of short rods which are ejected as such or as long gelatinous threads upon the addition of dilute methylene blue solution.



EUGLENOPHYCEAE

Colacium vesiculosum Ehr. Collected by R. Prettyman, March 10, 1937, in a bog known as "Bacon's Swamp," Marion County, Indiana. Attached to Cyclops. Genus not reported previously for the state.

HETEROKONTAE

Mischococcus confervicola Näg. Collected by R. Prettyman, March 23, 1937, in small pond, Marion County, Indiana. Genus is new for the state.

Botrydium granulatum (L.) Grev. Collected by Wm. A. Daily and C. M. Palmer, May 10, 1934, on the west bank of White river (west fork), Johnson County and Marion County, Indiana. The alga grew on a wet, sloping bank of earth in an area not more than 10 feet from the edge of the water extending intermittently for a distance of at least one-fourth of a mile. Species previously reported for 5 counties in the state.

Bishop

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